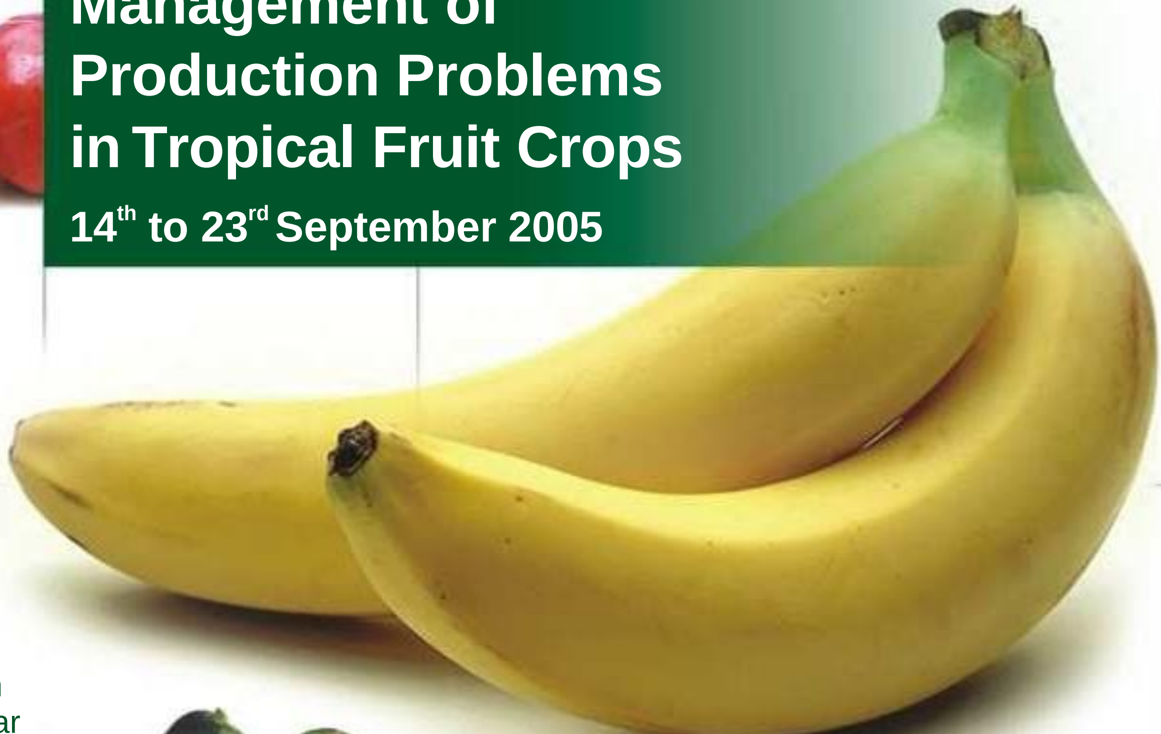
ICAR Sponsored Short Course

Management of Production Problems in Tropical Fruit Crops

14th to 23rd September 2005



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Ere(ace

India is one of the emerging countries having a strong footing in Agriculture, particularly in Horticulture. Though there are plenty of technologies to boost up the production, there are several other areas to be adequately addressed for sustainable production. With this in mind and to sensitize the teachers, researchers and extension workers, the Indian Council of Agricultural Research has given approval to conduct a short course on "Management of Production Problems in Tropical Crops" from 14th September to 23rd September, 2005 at the Department of Fruit Crops, HC&RI, TNAU, Coimbatore. We gratefully acknowledge the ICAR for having selected our faculty for this programme and for extending financial support.

Our sincere thanks are due to Dr.C. Ramasamy, Vice-chancellor, TNAU, Coimbatore for his encouragement and full support in conducting the short course.

The help rendered by the members of the faculty was immense and our thanks are due to them. Words are inadequate to express our gratitude for the sincere service by the members of the Department of Fruit Crops, without whom the training would not have been possible.

Thanks are due to the various State Agricultural Universities and ICAR Institutes for having nominated their scientists, extension workers and teachers to attend the short course. We also acknowledge the resource persons who readily agreed to deliver the technical inputs and spent their valuable time with the participants and provided the core input for the training.

Course Director and the Editors

Tamil Nadu Agricultural University

Dr. C. Ramasamy
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7oreword

India's diverse agro-climatic regions facilitate production of wide variety of fruits. Even though India leads the world in production of mango, banana, sapota and acid lime, in terms of productivity, it ranks far below than many countries. With trade barriers becoming narrower in the post WTO era, it is of paramount importance that the agricultural and horticultural production are kept at a higher level in a sustainable and competitive manner despite the increasing pressure on land and water. Our present status of export of fresh fruits is insignificantly low despite the climatic advantage we possess. Production problems and challenges faced by the grower need to be addressed constantly and urgently to keep production levels from falling. It is timely that the short course Management of Production Problems in Tropical Fruit Crops' sponsored by ICAR is organized at the Tamil Nadu Agricultural University to provide an update on various production problems of tropical fruit crops like banana, mango, papaya, grapes, sapota, citrus, guava, jack, aonla etc. to the researchers, teachers and extension personnel of horticulture from different parts of India.

As I understand, the program covers all relevant aspects like production strategies including biotechnological approaches, micro irrigation and fertigation, pests and disease management, post-harvest handling etc. I congratulate the contributors of the various topics and the editors for bringing out this compendium, which will not only be useful to the participants of the short course but also to the students of horticulture, researchers, teachers of state agricultural universities, extension workers, private establishments, enthusiastic growers with scientific approach and various agencies involved in promoting fruit production.

C. Ramasamy

Co te ts

Good Agricultural Eractices a d Ehytosa itatio Sta dards i 7ruit Crops

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The concept of Good Agricultural Practices (GAP) has evolved in recent years in the context of a rapidly changing and globalizing food economy and as a result of the concerns and commitments of a wide range of stakeholders about food production and security, food safety and quality, and the environmental sustainability of agriculture. These stakeholders include governments, food processing and retailing industries, farmers, and consumers, who seek to meet specific objectives of food security, food quality, production efficiency, livelihoods and environmental benefits in both medium and long term. GAP offers a means to help reach those objectives.

Broadly defined, GAP applies available knowledge to addressing environmental, economic and social sustainability for on-farm production and post-production processes resulting in safe and healthy food and non-food agricultural products. Many farmers in developed and developing countries already apply GAP through sustainable agricultural methods such as integrated pest management, integrated nutrient management and conservation agriculture. These methods are applied in a range of farming systems and scales of production units, including as a contribution to food security, facilitated by supportive government policies and programmes.

Good Agricultural Practices (GAP) is a set of principles to make agriculture less dependent on chemicals, less aggressive to the environment and more socially conscious, therefore, more sustainable. Good Agricultural Practices are procedures that improve conventional methods of production, beginning with the choice of the cultivation areas reaching until post-harvest procedures with emphasis in the health, well-being and safety of workers. They aim at healthy products and at the preservation of the environment promoting the addition of value to the products of small, medium and large farmers. These practices are the basis for other programs of stimulus to quality improvement, like the Hazards Analysis and Critical Control Points (HACCP) or for programs of promotion of agricultural certification such as Integrated Fruit Production and other international protocols for quality certification.

At present, GAP is formally recognized in the international regulatory framework for reducing risks associated with the use of pesticides, taking into account public and occupational health, environmental, and safety considerations. The use of GAP is also being promoted increasingly by the private sector through informal codes of practice and indicators developed by food processors and retailers in response to emerging consumer demand for sustainably produced and wholesome food. This trend may create incentives for the adoption of GAP by farmers by opening new market opportunities, provided they have the capacity to respond.

Good Agricultural Practices for Selected Agricultural Components

Soil

1. The physical and chemical properties and functions, organic matter and biological activity of the soil are fundamental to sustaining agricultural production and determine, in their complexity, soil fertility and productivity. Appropriate soil management aims to maintain and improve soil productivity by improving the availability and plant uptake of water and nutrients through enhancing soil biological activity, replenishing soil organic matter and soil moisture, and minimizing losses of soil, nutrients, and agrochemicals through erosion, runoff and leaching into surface or ground water. Though soil management is generally undertaken at field/farm level, it affects the surrounding area or catchment

due to off-site impacts on run-off, sediments, nutrients movement, and mobility of livestock and associated species including predators, pests and biocontrol agents.

2. Good practices related to soil include maintaining or improving soil organic matter through the use of soil carbon-build up by appropriate crop rotations, manure application, pasture management and other land use practices, rational mechanical and/or conservation tillage practices; maintaining soil cover to provide a conducive habitat for soil biota, minimizing erosion losses by wind and/or water; and application of organic and mineral fertilizers and other agro-chemicals in amounts and timing and by methods appropriate to agronomic, environmental and human health requirements.

Water

3. Agriculture carries a high responsibility for the management of water resources in quantitative and qualitative terms. Careful management of water resources and efficient use of water for rainfed crop and pasture production, for irrigation where applicable, and for livestock, are criteria for GAP. Efficient irrigation technologies and management will minimize waste and will avoid excessive leaching and salinization. Water tables should be managed to prevent excessive rise or fall.

4. Good practices related to water will include those that maximize water infiltration and minimize unproductive efflux of surface waters from watersheds; manage ground and soil water by proper use, or avoidance of drainage where required; improve soil structure and increase soil organic matter content; apply production inputs, including waste or recycled products of organic, inorganic and synthetic nature by practices that avoid contamination of water resources; adopt techniques to monitor crop and soil water status, accurately schedule irrigation, and prevent soil salinization by adopting water-saving measures and re-cycling where possible; enhance the functioning of the water cycle by establishing permanent cover, or maintaining or restoring wetlands as needed; manage water tables to prevent excessive extraction or accumulation; and provide adequate, safe, clean watering points for livestock.

Crop and Fodder Production

5. Crop and fodder production involves the selection of annual and perennial crops, their cultivars and varieties, to meet local consumer and market needs according to their suitability to the site and their role within the crop rotation for the management of soil fertility, pests and diseases, and their response to available inputs. Perennial crops are used to provide long-term production options and opportunities for intercropping. Annual crops are grown in sequences, including those with pasture, to maximize the biological benefits of interactions between species and to maintain productivity. Harvesting of all crop and animal products removes their nutrient content from the site and must ultimately be replaced to maintain long-term productivity.

6. Good practices related to crop and fodder production will include those that select cultivars and varieties on an understanding of their characteristics, including response to sowing or planting time, productivity, quality, market acceptability and nutritional value, disease and stress resistance, edaphic and climatic adaptability, and response to fertilizers and agrochemicals; devise crop sequences to optimize use of labour and equipment and maximize the biological benefits of weed control by competition, mechanical, biological and herbicide options, provision of non-host crops to minimize disease and, where appropriate, inclusion of legumes to provide a biological source of nitrogen; apply fertilizers, organic and inorganic, in a balanced fashion, with appropriate methods and equipment and at adequate intervals to replace nutrients extracted by harvest or lost during production; maximize the benefits to soil and nutrient stability by re-cycling crop and other organic residues; integrate livestock into crop rotations and utilize the nutrient cycling provided by grazing or housed livestock to benefit the fertility of the entire farm; rotate livestock on pastures to allow for healthy re-growth of pasture; and adhere to safety regulations and observe established safety standards for the operation of equipment and machinery for crop and fodder production.

Crop Protection

7. Maintenance of crop health is essential for successful farming for both yield and quality of produce. This requires long-term strategies to manage risks by the use of disease- and pest-resistant crops, crop and pasture rotations, disease breaks for susceptible crops, and the judicious use of agrochemicals to control weeds, pests, and diseases following the

principles of Integrated Pest Management. Any measure for crop protection, but particularly those involving substances that are harmful for humans or the environment, must only be carried out with consideration for potential negative impacts and with full knowledge and appropriate equipment.

8. Good practices related to crop protection will include those that use resistant cultivars and varieties, crop sequences, associations, and cultural practices that maximize biological prevention of pests and diseases; maintain regular and quantitative assessment of the balance status between pests and diseases and beneficial organisms of all crops; adopt organic control practices where and when applicable; apply pest and disease forecasting techniques where available; determine interventions following consideration of all possible methods and their short- and long-term effects on farm productivity and environmental implications in order to minimize the use of agrochemicals, in particular to promote integrated pest management (IPM); store and use agrochemicals according to legal requirements of registration for individual crops, rates, timings, and pre-harvest intervals; ensure that agrochemicals are only applied by specially trained and knowledgeable persons; ensure that equipment used for the handling and application of agrochemicals complies with established safety and maintenance standards; and maintain accurate records of agrochemical use.

Animal Production

9. Livestock require adequate space, feed, and water for welfare and productivity. Stocking rates must be adjusted and supplements provided as needed to livestock grazing pasture or rangeland. Chemical and biological contaminants in livestock feeds are avoided to maintain animal health and/or to prevent their entry into the food chain. Manure management minimizes nutrient losses and stimulates positive effects on the environment. Land requirements are evaluated to ensure sufficient land for feed production and waste disposal.

10. Good practices related to animal production will include those that site livestock units appropriately to avoid negative effects on the landscape, environment, and animal welfare; avoid biological, chemical, and physical contamination of pasture, feed, water, and the atmosphere; frequently monitor the condition of stock and adjust stocking rates, feeding, and water supply accordingly; design, construct, choose, use and maintain equipment, structures, and handling facilities to avoid injury and loss; prevent residues from veterinary medications and other chemicals given in feeds from entering the food chain; minimize the non-therapeutic use of antibiotics; integrate livestock and agriculture to avoid problems of waste removal, nutrient loss, and greenhouse gas emissions by efficient recycling of nutrients; adhere to safety regulations and observe established safety standards for the operation of installations, equipment, and machinery for animal production; and maintain records of stock acquisitions, breeding, losses, and sales, and of feeding plans, feed acquisitions, and sales.

Animal Health and Welfare

11. Successful animal production requires attention to animal health that is maintained by proper management and housing, by preventive treatments such as vaccination, and by regular inspection, identification, and treatment of ailments, using veterinary advice as required. Farm animals are sentient beings and as such their welfare must be considered. Good animal welfare is recognized as freedom from hunger and thirst; freedom from discomfort; freedom from pain, injury or disease; freedom to express normal behaviour; and freedom from fear and distress.

12. Good practices related to animal health and welfare will include those that minimize risk of infection and disease by good pasture management, safe feeding, appropriate stocking rates and good housing conditions; keep livestock, buildings and feed facilities clean and provide adequate, clean bedding where livestock is housed; ensure staff are properly trained in the handling and treatment of animals; seek appropriate veterinary advice to avoid disease and health problems; ensure good hygiene standards in housing by proper cleansing and disinfection; treat sick or injured animals promptly in consultation with a veterinarian; purchase, store and use only approved veterinary products in accordance with regulations and directions, including withholding periods; provide adequate and appropriate feed and clean water at all times; avoid non-therapeutic mutilations, surgical or invasive procedures, such as tail docking and debeaking; minimise transport of live animals (by foot, rail or road); handle animals with appropriate care and avoid the use of

instruments such as electric goads; maintain animals in appropriate social groupings where possible; discourage isolation of animals (such as veal crates and sow stalls) except when animals are injured or sick; and conform to minimum space allowances and maximum stocking densities.

Harvest and On-farm Processing and Storage

13. Product quality also depends upon implementation of acceptable protocols for harvesting, storage, and where appropriate, processing of farm products. Harvesting must conform to regulations relating to pre-harvest intervals for agrochemicals and withholding periods for veterinary medicines. Food produce should be stored under appropriate conditions of temperature and humidity in space designed and reserved for that purpose. Operations involving animals, such as shearing and slaughter, must adhere to animal health and welfare standards.

14. Good practices related to harvest and on-farm processing and storage will include those that harvest food products following relevant pre-harvest intervals and withholding periods; provide for clean and safe handling for on-farm processing of products. For washing, use recommended detergents and clean water; store food products under hygienic and appropriate environmental conditions; pack food produce for transport from the farm in clean and appropriate containers; and use methods of pre-slaughter handling and slaughter that are humane and appropriate for each species, with attention to supervision, training of staff and proper maintenance of equipment.

Energy and Waste Management

15. Energy and waste management are also components of sustainable production systems. Farms require fuel to drive machinery for cultural operations, for processing, and for transport. The objective is to perform operations in a timely fashion, reduce the drudgery of human labour, improve efficiency, diversify energy sources, and reduce energy use.

16. Good practices related to energy and waste management will include those that establish input-output plans for farm energy, nutrients, and agrochemicals to ensure efficient use and safe disposal; adopt energy saving practices in building design, machinery size, maintenance, and use; investigate alternative energy sources to fossil fuels (wind, solar, biofuels) and adopt them where feasible; recycle organic wastes and inorganic materials, where possible; minimize non-usable wastes and dispose of them responsibly; store fertilizers and agrochemicals securely and in accordance with legislation; establish emergency action procedures to minimize the risk of pollution from accidents; and maintain accurate records of energy use, storage, and disposal.

Human Welfare, Health and Safety

17. Human welfare, health and safety are further components of sustainability. Farming must be economically viable to be sustainable. The social and economic welfare of farmers, farm workers, and their communities depends upon it. Health and safety are also important concerns for those involved in farming operations. Due care and diligence is required at all times. With regard to agricultural workers, the ILO in collaboration with governments, employers and trade unions, has developed core conventions on labour including codes of practice for agriculture, which have not been specifically included in the indicators and practices.

18. Good practices related to human welfare, health and safety will include those that direct all farming practices to achieve an optimum balance between economic, environmental, and social goals; provide adequate household income and food security; adhere to safe work procedures with acceptable working hours and allowance for rest periods; instruct workers in the safe and efficient use of tools and machinery; pay reasonable wages and not exploit workers, especially women and children; and purchase inputs and other services from local merchants if possible.

Wild life and Landscape

19. Agricultural land accommodates a diverse range of animals, birds, insects, and plants. Much public concern about modern farming is directed at the loss of some of these species from the countryside because their habitats have been destroyed. The challenge is to manage and enhance wildlife habitats while keeping the farm business economically viable.

20. Good practices related to wildlife and landscapes will include those that identify and conserve wildlife habitats and landscape features, such as isolated trees, on the farm; create, as far as possible, a diverse cropping pattern on the farm; minimize the impact of operations such as tillage and agrochemi-

cal use on wildlife; manage field margins to reduce noxious weeds and to encourage a diverse flora and fauna with beneficial species; manage water courses and wetlands to encourage wildlife and to prevent pollution; and monitor those species of plants and animals whose presence on the farm is evidence of good environmental practice.

Benefits of GAP Will Accrue to:

- small, medium and large-scale farmers, who will achieve added value for their produce and better access to markets;
- consumers, who will be assured of better quality and safer food, produced in sustainable ways;
- business and industry, who will gain profit from better products; and
- all people, who will enjoy a better environment.

Although methodologies such as Integrated Pest Management and Conservation Agriculture have evolved to address specific production issues, and food quality standards are established through the *Codex Alimentarius*, the agricultural sector lacks a unifying framework to guide national debate and action on policies and methods to achieve sustainable agriculture. The need for action is evident from the widespread concern over the biological, ecological, economic and social aspects of sustainability of existing agricultural production systems. Enormous gains in productivity and efficiency have been achieved through technology, innovation, and mechanization but at some cost to the environment. At the same time, the struggle for food security with inadequate inputs and technology in developing countries is exhausting the natural resource base without satisfying the need. In addition, concern is growing in all parts of the world over the safety of agricultural and livestock products.

There is need for a rapid transition to sustainable production systems and management of the natural resources upon which humankind relies. Such systems will closely integrate biological and technological inputs, will more completely capture the costs of production, sustain productivity and ecological stability, and restore consumer confidence in their products and methods of production.

To attain these goals, there is an urgent need to raise awareness among all stakeholders and governments, in particular farmers and consumers, on what constitutes sustainable agriculture. Governments and private institutions need to enact and implement supportive policies. Farmers will respond to incentives of improved market access and added value by adopting those production methods that satisfy the demands of processors and consumers. For this, individual farmers require unambiguous guidance of what is required and how it can be implemented. Farmers must be efficient and competitive but at the same time they must receive adequate prices for their products.

Some GAP programmes are market-driven. These can be private sector supply chain-driven systems where a key player in the supply chain, e.g. the retailer, introduces a set of proprietary GAP guidelines for its suppliers. Alternatively, private sector initiatives can be sector-wide being driven by industry groups, with key roles played by retailer and/or producer associations in developing guidelines. Examples include the retailer-led EUREPGAP.

Other initiatives are the realm of 'public sector' action and may be developed by governments within the national policy frameworks of individual countries to enhance domestic competitiveness. For example, the Malaysian Department of Agriculture is implementing a voluntary farm accreditation scheme to encourage the adoption of GAPs among fruit and vegetable producers, particularly the use of integrated pest management (Agricultural Technical Co-operation Working Group(ATCWG)). Finally, Non-Governmental Organisations (NGOs) and international agencies have also actively promoted the use of GAPs. The Integrated Pest Management and the Better Banana project are programmes promoted by NGOs that encourage the use of GAPs.

Applications of GAP

- Governments, international agencies and NGOs promote sustainable agricultural methods such as integrated pest management, integrated nutrient management and conservation agriculture, among others, aimed at mitigating specific environmental and societal risks in a range of production and farming systems. IPM is specified as a recommended practice in the Code of Conduct on Pesticides and in Chapter 14 of Agenda 21. These methods are especially appropriate for small- or medium-scale farmers in developing countries, contribute to increased local food production and food security, and conserve natural resources.
- National agencies have also promoted GAP for both quality assurance and environmental management.

These include the government agencies of Canada, France, Malaysia, New Zealand, Uruguay, the United Kingdom and the United States. Latvia, Lithuania and Poland have adopted good practices with respect to the Baltic agricultural runoff programme. The national agricultural research organization of Brazil, EMBRAPA, in collaboration with FAO, is developing a series of specific technical guidelines for melons, mangoes, fruit and vegetables, field crops, dairy, beef, swine and poultry, based on GAP to be tested by small, medium and large-scale producers.

- The private sector, in particular industrial processors and retailers, uses GAP with a view to attaining quality assurance, consumer satisfaction and profit in the production of safe and high quality food along the food chain. These efforts increasingly incorporate sustainability criteria in response to consumer demand. Examples include the EUREPGAP generic Codes of Practice for fresh produce, combinable crops and livestock; the Sustainable Agriculture Initiative (Unilever, Nestlé, Danone and others); and, the EISA Common Codex for Integrated Farming. Unilever has developed more specific "sustainable agriculture indicators" of achievement for specific crops and locations. The promotion of GAP by food processors and retailers can facilitate the adoption of sustainable agricultural practices by creating incentives through potential value-added opportunities for farmers.
- NGOs are also working to address good practices, in particular for food crops. For example, the Better Banana Project, managed by a coalition of non-profit conservation groups and coordinated by the Rainforest Alliance promotes sustainability by certifying banana farms based on nine guiding principles. This address - among other elements - production practices, wildlife protection, and worker safety.
- A further concrete example of the GAP approach is precise standards for organic production aimed at achieving optimal sustainable agro-ecosystems. These standards have been extensively elaborated to provide the basis for meeting growing consumer demands for production without the use of chemical fertilizers, pesticides, GMOs and other practices proscribed for organic agriculture. The Codex guidelines on organically produced food refer to the production process itself and aim to protect the consumer against misleading claims, protect organic producers from misrepresentation and guide governments in setting standards for the production, processing and labelling of organic produce.
- A specific version of GAP is applied within established codes of practice for food safety, under Codex Alimentarius, to minimize or prevent contamination of food. The Codex Alimentarius Commission develops and adopts standards, guidelines and related texts on all aspects of food safety and quality reflecting consensus at the international level. Codex standards are reference points for developing and harmonizing national standards. Codex defines GAP in the use of pesticides to include "...nationally authorized safe uses of pesticides under actual conditions necessary for effective and reliable pest control" . The actual conditions include any stage of the production, storage, transport, distribution and processing of food commodities and animal feed. GAP in this context is used to set maximum residue levels for pesticides and is also recognized in the International Code of Conduct on the Distribution and Use of Pesticides.
- While the Codex Alimentarius specifically defines GAP in the context of the use of pesticides, the Code of Practice (General Principles of Food Hygiene) and other more specific codes, address good practices in primary production as well as post-production systems. Some national programmes have extended the use of the term Good Agricultural Practices to refer to practices to minimize microbial food safety hazards in fresh produce.

Codes and Standards with Government Involvement

A limited definition of GAP is applied within established codes of practice for food safety, under Codex Alimentarius, to minimize or prevent contamination of food. The Codex Alimentarius Commission develops and adopts standards, guidelines and related texts on all aspects of food safety and quality reflecting consensus at the international level. Codex standards subsequently constitute reference points for developing and harmonizing national standards. Codex defines GAP in the use of pesticides to include "...nationally authorized safe uses of pesticides under actual conditions necessary for effective and reliable pest control". The actual conditions include any stage of the production, storage, transport, distribution and processing of food commodities and animal feed. GAP in this context is used to define maximum residue levels for pesticides.

Also in the International Code of Conduct on the Distribution and Use of Pesticides, Integrated Pest Management is specified as a recommended practice, with the scope of controlling pesticides residue levels.

While the Codex Alimentarius and the International Code specifically define GAP in the context of the use of pesticides, the Codex Code of Practice (General Principles of Food Hygiene) and other more specific codes, address good practices in primary production as well as post-production systems. Some national programmes have extended the use of the term Good Agricultural Practices to refer to practices to minimize microbial food safety hazards in fresh produce.

Hazard Analysis and Critical Control Points (HACCP) is widely adopted in the food processing industry as a risk management tool that provides a structured approach the control of hazards in processing and manufacturing. HACCP has been incorporated into The Codex Alimentarius (FAO/WHO) and in the U.S. has become a legal requirement for the fish, poultry and meat industries. The essential feature of the technique is the thorough analysis of production flow charts to identify the critical control points where care is required to maintain specified aspects of product quality and also integrity of the infrastructure. Management monitors these control points and seeks to maintain them within acceptable ranges. The result is the maintenance of product quality. HACCP is now also finding application in environmental management and so is a key technique in both the quality assurance (QA) and environmental management (EM) aspects of Good Farming Practice (GFP).

Certification and Labelling with Government Involvement

ISO 14001

Although ISO 14001 is not a (inter)governmental standard, governments are involved in or endorse the ISO system as a whole. ISO, founded in 1947, has long been recognized as the major standard setting body for voluntary international harmonized industry standards. ISO declares to be a not-for-profit non-governmental organization. Its member bodies are governmental, parastatal, tripartite or non-governmental bodies, the latter often consisting of industry representatives. There can only be one ISO member per country. Only recently has ISO started to develop environmental standards and initiated work on social responsibility.

Organic standards and certification

Organic production is a holistic management of the agro-ecosystem, emphasizing biological processes and minimizing the use of non-renewable resources. Although the terms “organic”, ecological” or “biological” have developed in Europe and North America to distinguish from conventional agriculture, many low-input traditional agriculture systems in other parts of the world are also *de facto* organic systems. In this respect the term “organic by default” has been introduced and even “organic by neglect”. However, these terms do give the false impression that any agriculture systems in which no agrochemicals are used would automatically comply with organic standards, which is not necessarily the case.

The International Federation of Organic Agriculture Movements (IFOAM) was founded in 1972. IFOAM formulated the first version of the IFOAM Basic Standards (IBS) in 1980 and has revised them biennially ever since. The IBS serves as a guideline on the basis of which national and private standard setting bodies can develop more specific organic standards.

With the growing market for organic products and supply lagging behind, price premiums provided an incentive to cheat. In reaction, many countries developed national organic regulations to protect reliable organic producers and consumers against misleading organic claims. The first organic regulations were adopted in the US (The States of Oregon, 1974 and California, 1979), France (1985), the EU (regulation 2092/91 of 1991), the JAS organic standards for plant products (2000) from the Japanese Ministry of Agriculture, Forestry and Fisheries, and standards of the US National Organic Program (NOP) developed by the US Department of Agriculture (2002). With a view to harmonization the FAO/WHO Codex Alimentarius Commission formulated guidelines for labelling of organically produced food, adopted in 1999 for vegetal products. The Codex guidelines are voluntary, member countries can choose the extent to which they follow them.

Organic standards cover all crops and mostly all livestock. Standards for fish farming, bee-keeping and harvesting of wild products are increasingly being developed by the various standard setting bodies. Organic standards for plant production typically include criteria for conversion periods; seeds and propagation material; maintenance of soil fertility through the use and recycling of organic materials; and pest, disease and weed control. The use of synthetic fertilizers and pesticides and of genetically engineered organisms is prohibited. There are also criteria for the admission and use of organic fertilizers and natural pesticides.

The International Organic Accreditation Service (IOAS) accredits certification bodies that have organic certification programmes that comply with the IFOAM Basic Standards and the IFOAM Criteria for Certification Bodies. Because the IBS is a generic standard, the IOAS requires that certification bodies elaborate some standards in more detail. The IFOAM accredited seal may appear on the product only as part of the logo of the certification body and in the bodies own promotional material.

Standards set by Farmers and Industry

Eurepgap

EUREPGAP is a private certification system driven by 22 large-scale retail chains and large fresh produce suppliers/producers in Europe that form the core members of the Euro-Retailer Produce Association (EUREP). There are also associate members (mainly suppliers of agrochemicals, certification bodies and consultancy firms) who may participate in meetings but are not part of the EurepGap decision-making process. Initially the EHI-EuroHandelsinstitut e.V. acted as international secretariat.

COLEACP Harmonized Framework

The COLEACP is an inter-professional association of exporters, importers and other stakeholders of the EU-ACP horticultural trade. To improve market recognition of ACP produce and respond to market demands for environmentally and socially responsible conditions of production, COLEACP took the initiative to encourage horticultural export associations to move towards harmonization of their Codes of Practice. The COLEACP Harmonized Framework is meant as a minimal set of food safety, environmental and social standards to be incorporated into national codes.

The European Initiative for Sustainable Development in Agriculture (EISA) and Related Codes of Integrated Farming

Over the past decade, inter-professional associations have been established in different European countries to develop codes of conducts and/or labels for Integrated Farming. These are in particular: FARRE (Forum de l'Agriculture Raisonnée Respectueuse de l'Environnement or Forum for Environment-Friendly Integrated Farming; France), FNL (Fördergemeinschaft Nachhaltige Landwirtschaft, Association for the Promotion of Sustainable Agriculture, Germany), LEAF (Linking Environment and Farming, United Kingdom), ODLING I BALANS (Sweden), FILL (Luxembourg) et L'Agricoltura che Vogliamo (Italy). In addition to primary producers, their members include farmers organizations, agricultural inputs suppliers, the agro-food industry and major retailers, and environmental groups.

Standards set by NGOs

Sustainable Agriculture Program of SAN/ Rainforest Alliance

The Sustainable Agriculture Network (SAN, formerly Conservation Agriculture Network (CAN)) is a coalition of ten conservationist NGOs in the Americas. The programme initially focussed on the environmental impact of production methods and habitat conservation, but has increasingly incorporated standards for community relations and labour conditions. The Rainforest Alliance is the main force behind the initiative.

The "Better Banana Project" and "ECO-OK" seals are being replaced by a new label "Rainforest Alliance Certified" in 2003. The label is administered by the Rainforest Alliance and they charge a fee for use, although this fee may be waived. The seals are used mostly in public relations activities of certified producers, and in relations between producers and buyers (importers, wholesalers and retailers), but have been used little on the products themselves, except for coffee and orange juice in the Americas and Japan. Companies that consider their own trade mark as a quality mark are hesitant to use an additional label. Furthermore, in Europe the ECO-OK label could not be used because the term "eco" is legally reserved for organic claims.

If Good Agricultural Practices appropriate to a particular crop, economic situation, and physical surroundings are adopted, farmers will be doing their part to ensure the safety of their customers. The consumer depends on the farmer for their well being, and provides the farmer, in turn, with his livelihood. Good Agricultural Practices will help to safeguard that livelihood.

"Food Safety is Everyone's Responsibility"

A Overview o(Eroductio Co strai ts a d Ma ageme t i Yropical 7ruit Crops

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India's diverse agro-climatic regions facilitate production of wide variety of fruits and vegetables. According to FAO statistics, India produces nearly 160 million tonnes of fruits and vegetables, and ranks second in the global map. In the year 2003, India produced nearly 45 million tonnes of fruits (Table 1) and over 110 million tonnes of vegetables, and accounted for nearly 10 per cent of global production in each category. The operational holdings of agriculture in India are about 170 million ha. Over the past decade, the increase in area and production is around 30 per cent and 54 per cent respectively (Chadha, 2001). Fruits and vegetables are produced in over 12 million hectares. Major fruits grown in India include bananas, mangoes, oranges, apples, grapes, pineapples, papayas and melons.

Global Scenario

In the global map, India is the top producer of mangoes and bananas. The domestic market was the main destination for most of India's fruit and vegetable production. Nearly, three-fourths of fruits and vegetables were consumed in the domestic market itself. While about 2 % of fruits and vegetables produced in India are being further processed, only about 1 % of the total production is being exported to various markets. Over 20 % of the production accounted for loss in value or wastage. Considering the recommended per capita dietary allowance of 120 g per day, post harvest losses, processing requirements and the population growth, the current national demand works out to 63.25 million tones (Singh and Samuel, 2000).

Indian Scenario

Banana is the major fruit crop grown in India accounting for over one-third of total fruit production. Other major fruit crops produced in India include mangoes (23 %), oranges (7 %), apples (3 %), grapes (3 %), pineapples and papayas (2 % each). India harvested

Table 1. Global production of fruits

Country	2003 (million tonnes)
China	72.20
India	**45.91**
Brazil	34.06
USA	29.12
Spain	10.85

FAOSTAT (2003)

approximately 4 mha of fruits in the year 2003. India's exports of fruits (including edible nuts) in the year 2003-04 accounted to US $ 166 million. The exports have witnessed a growth of nearly 78 % over the previous year. Exports of fruits accounted for 0.26 % share in India's total exports in 2003-04. Major markets to which Indian fruits are being exported include UAE, Bangladesh, Saudi Arabia, UK and the Netherlands. India's share in global imports accounts for 0.5 % in fruits and ranked 32 in the world.

India leads the world in production of mango, banana, sapota and acid lime. However, the productivity is low, which is merely 11.8 t/ha when compared to other leading countries producing similar crops. Maharastra, Karnataka, Andhra Pradesh, Bihar and Uttar Pradesh are the major fruit producing states, which put together, occupy 52 % of total area and 55 % of total national production. The productivity is very high in Madhya Pradesh (27.5 t/ha) as compared to Tamil Nadu (25.9 t/ha), Karnataka (14.7 t/ha), Maharastra (16.4 t/ha) and Andhra Pradesh (11.2 t/ha), while the lowest productivity in Sikkim (Table 2). The demand for horticultural produce will continue to rise with rise in income. The overall demand projection worked out for various horticultural crops is to the tune of 268.22 million tones by 2007-08 (Table 3).

Comparison of the value of exports by India with the level of imports in most of the countries concluded that India's average market share works out to approximately 15 per cent. While India holds high market

Table 2. Area, production and productivity of fruits (2000-01)

States	Area (in 000' ha)	Production (in 000'MT)	Productivity (in MT / ha)
Tamil Nadu	240.4	6237.7	25.9
Madhya Pradesh	63.2	1740.4	27.5
Karnataka	326.9	4819.5	14.7
Maharastra	529.3	8680.8	16.4
Andhra Pradesh	448.0	5003.4	11.2
Sikkim	9.4	10.0	1.1

(HORT STAT, 2003)

Table 3. Projected demand of horticulture produce (million tonnes)

Commodity	Production		Projection	
	1997-98	1998-99	2001-02	2007-08
Fruits	43.26	44.04	55.10	75.00
Vegetables	72.70	87.53	108.00	160.00
Spices	2.76	2.87	4.10	5.00
Coconut	8.75	10.27	12.50	18.00
Cashew nut	0.36	0.46	1.00	1.50
Cocoa and others	1.5	1.65	3.00	6.00
Total	129.33	146.82	183.70	265.50

(H.P. Singh and K.L.Chadha, 2001)

share in countries like Sri Lanka, Maldives, Nepal and Bangladesh, it's share is relatively less in countries like Saudi Arabia, Singapore, Israel, Kuwait, Pakistan, Oman and Brunei. In the long term, however, India should strive to achieve reasonable market share in countries like Japan, Hong Kong, China, Indonesia and Philippines.

Major problems that come across while exporting fresh fruits from India include low productivity (cost competitiveness) as compared to global standards, prevalence of low level of pre- harvest and post- harvest technologies, international quality standards and existence of distortion in market channels. It is time to bring in paradigm shift so that the future development in this sector brings in better balance between production and other sub-systems, *viz.*, preharvest technologies, post harvest processing, quality management, export infrastructure, supply chain, market information and marketing strategies.

Production constraints

Over the years, productivity and quality of several horticultural crops have continued to remain much below the potential, demonstrated in research trials. There are various factors, which contribute to low productivity. They are:

1. **Low productivity** of crops due to
   a. Poor quality planting materials of improved cultivars, inferior genetic stocks and poor management.
   b. Lack of mechanism for assessing quality of planting materials.
   c. High risk of transmission of virus diseases from one generation to other, in propagated materials.
   d. Predominance of old and senile orchards which needs replacement / rejuvenation.

e. Vast majority of holdings are small and rainfed.

f. Unawareness about the Hi-technology, poor capacity of farmers to invest and poor credit support coupled with problems of infrastructure.

g. Lack of knowledge on seasonal growing to meet the export demands.

2. **Inferior quality** of produce due to

a. Poor post-harvest management.

b. Absence of infrastructural facilities for handling and storage.

c. Absence of efficient marketing system coupled with seasonality and perishability.

d. Weak processing infrastructures.

e. Lack of adequate standards for quality produce.

f. High capital investment hinders effective utilization of raw materials.

3. **The high capital cost** involved in establishing an orchard/ plantation as also setting up of required infrastructure is a serious constraint in expansion of area under many horticultural crops as well as improvement in existing orchards.

4. **The long gestation period** results in a wide variation in the credit availability in different parts of the country, being the highest in Kerala ie, more than Rs 5000/ ha of land compared to Rs 50 /ha in Bihar.

5. Unless the **database** is made authentic and broader in its coverage, long-term planning for horticultural development will be difficult and unrealistic.

6. High incidence of **pests and diseases**.

7. **Chronic production problems** due to major disorders like alternate bearing, malformation and spongy tissue in mango, guava wilt, citrus decline, *Phytophthora* diseases in large number of crops etc. remain largely unresolved.

8. Lack of technologies for the improvement in **wastelands and hilly terrains** being the potential future expansion areas.

9. No improved technologies for the large scale production of **underutilized crops** which are best suited for wastelands, and poor and marginal soils.

Future Strategies

1. Rationalization of Research

There is a need to shift from commodity/discipline oriented research to system based research and to establish stronger Inter-institutional linkages with State Agricultural Universities (SAUs), Council for Scientific and Industrial Research (CSIR), Department of Biotechnology (DBT) and Bhaba Atomic Research Centre (BARC). Greater private sector partnership for diversification, value addition and export promotional research and seed production programmes will be required to modernize horticulture industry. Introduction of project based budgeting in the Institutes/NRCs will bring better accountability and one time catch up grant to modernize old Institutes will be essential. Development of database on technologies evolved, market intelligence, export projections/removal of quantitative restrictions, R&D scenario in horticulture should receive priority attention.

2. Safeguard for Intellectual Property Rights (IPR)

A full proof description of varieties and their registration and finalisation of material transfer agreement and channelization of germplasm exchange need to be institutionalized. Similarly, specification of quality/codex standard for export of indigenous fruits and vegetables need to be developed. Phytosanitary regulations for importing vegetatively propagated materials need a relook/revision and rigorous enforcement.

3. Genetic Resources

- Widening genetic base in mango (*Mangifera* species of South East Asia), Citrus (newly developed rootstocks), guava (coloured varieties), papaya (species and varieties).
- Enrichment of various germplasm collections with species/ cultivars which are high yielding and resistant/tolerant to different biotic and abiotic stresses.
- Standardize long term techniques for cryopreservation of propagating materials and pollen grains.

- In situ conservation of endangered genetic wealth.

4. Crop Improvement

- Development of dwarf rootstocks/ scion varieties for high density planting and export in mango, sapota, citrus, ber *etc.*
- To induce and exploit useful genetic changes through mutations in commercial cultivars.
- Development of rootstocks and scion varieties in fruits resistant/tolerant to major biotic and abiotic stresses, e.g. malformation in mango, guava rootstocks for wilt, citrus rootstocks against *Phytophthora*, frost and PRV resistance in papaya.

5. Improving Crop Production

- Standardise rootstocks for all important fruit crops e.g. mango, guava, sapota and ber.
- To develop horticultural crop based cropping systems for different agro-ecological regions.
- To develop integrated nutrient management system i.e. efficient utilization of chemical fertilizers, use of bio-fertilizers and addition of organic material using leaf nutrient standards.
- Standardize water management practices in major crops including micro-irrigation and fertigation.
- Develop techniques of organic farming for export oriented fruit crops.
- Standardize production technology for quality crops for export e.g. mango, grapes etc.

6. Improving crop productivity

- Production of disease-free, quality materials of only released and recommended varieties/hybrids both in the public and private sectors.
- Improving efficiency by gap filling and rejuvenation of old, unproductive, senile plantations through substitution of old varieties with improved high-yielding varieties of crops like mango, cashew etc.
- High-density planting by reduction in planting distance or use of plant growth inhibitors and dwarfing rootstocks as recommended in crops like mango and citrus.
- Promoting cultivation of crops, which produce higher biomass/unit time, e.g., banana, pineapple, papaya in areas requiring poverty-alleviation and nutritional security.
- Use of plant growth regulators and chemicals for improving productivity. Paclobutrazol- mango and GA_3 – grapes.
- Application of frontier technologies (Hi-tech horticulture) e.g. micro-irrigation, fertigation, INM, etc. for improving productivity of high value crops.

7. Crop Protection

- Develop IPM strategies for important pests of commercial crops.
- Develop biological control for important diseases and insects affecting commercial crop production.
- Management of pests and diseases should never account for environment pollution and pesticide residue problems.

8. Export Promotional Research

There is a need for development of bulk handling system of tropical fruits, including pre-cooling and CA/ MA storage and post harvest protocols for sea transport of major fruits like banana, mango, litchi, sapota, kinnow and pomegranate. Disinfestation technology including vapour heat treatment (VHT) for export of fresh fruits and extension of shelf life by preventing desiccation should help in further export promotion.

9. Post Harvest Management

- To reduce losses occurring during harvesting, storage and transport and improve shelf life of perishable horticultural commodities.
- To conduct basic and applied research in CA/ modified atmospheric storage of high value perishable crops.
- Improve indigenous low cost storage systems developed for fruit crops.
- Develop techniques for bulk preservation of fruit pulps. Improve drying systems for raisins.
- Utilization of wastes for development of economically viable products.

· Development / fabrication of low energy requiring machinery for horticultural crop cultivation.

10. Biotechology

- To standardise *in vitro* culture techniques for mass multiplication of rootstock/scion of difficult to micro propagate plants like mango, guava, sapota.
- To identify molecular markers based on RAPD and RFLP in important horticultural crop varieties.
- Genetic engineering for integration of desirable traits
- Develop transgenic plants with endogenous resistance to insect pests eg. Bacterial canker in kagzi lime and virus free materials.
- Preservation of post harvest losses through control of metabolic process.

11. Human Resource Development

Advanced training in research methodologies and instrumentation, biotechnology, micro-irrigation, fertigation, IPM, INM, biofertilizer, biopesticide, pesticide residue, PHT and product development need priority attention for increasing research capabilities of the scientists. Skill development for state level development functionaries through in-service training at different R&D institutions will enhance capabilities of extension staff. Post Graduate programmes in fruit, vegetable, floriculture, plantation crops and post harvest management of horticultural crops will help in providing trained manpower in specialized areas.

Technology adoption pattern can not be uniform throughout the country and will vary from crop to crop and even from region to region. Certain degree of flexibility in research planning and research strategy is therefore obvious. Also, with the opening of global markets and removal of quantitative restrictions under the WTO export-import scenario is likely to change at much faster pace. Market forces will play a more dominant role and demands for modern technologies will increase. Research system in horticulture will have to be very alert and should be able to adjust with the changes. Development of both short term and long term strategies for modernising Indian horticulture will depend largely on the research support and strength of research system.

Emphasis on HRD to ensure efficient transfer of technologies are:

- Development of strong database in horticultural crops.
- Organizing management training programmes for plantation managers at suitable horticultural and plantation crops institutes.
- Organizing study tours for small and marginal farmers.
- Organizing training programmes on modern aspects and adoption of of latest technologies regarding production, pre and post-harvest management, handling of produce for domestic and export markets.

12. Policy Issues

- Create facilities for enhancing shelf-life of mango, grape and litchi through the use of controlled / modified atmosphere/refrigerated containers.
- Horticultural produce should also be included under Hazard Analysis Critical Control Points (HACCP) Certification Programme.
- The basic principles of WTO agreement are, non-discrimination, reciprocity, market access and fair competition. Since, India is signatory to WHO agreement, it has to fulfill certain agreements under WTO regime. Hence, there is need for creating awareness on the implications of WTO regime among horticultural entrepreneurs as well as small and marginal farmers.
- As a long-term measure, focused attention needs to be paid to efficient horticultural cropping zones not only to achieve cost efficiency in production but also to attain international quality standards prescribed by various importing countries.
- Sanitary and phyto-sanitary standards already available in India for fresh horticultural produce should be immediately harmonized with the international guidelines and if higher level of measures is required, the scientific justification for the same should be documented at the earliest.
- New opportunities like organic farming, import substitution, import information system and the products, which have edge in international market, need to be promoted for sustained advantage and profit.
- The strength of Indian Horticulture needs to be capitalized to provide leadership for overall

development of horticulture in the region with the involvement of other countries and organizations like FAO.

Conclusions

India has a good natural resource base with an adequate R&D infrastructure and excellence in several areas. As a result, the horticultural scenario of the country has been changing fast. Both production and productivity of several crops has increased manifold and India can boast itself as a leading horticultural country of the world. Many new crops have been introduced and many others have adapted to non conventional areas. Some other crops are under adaptive trials. Export of fresh as well as processed fruits has been increasing. The demand of horticulture produce is on the rise due to increasing population, changing food habits, realisation of high nutritional value of horticultural crops and greater emphasis on value addition and export. However, several challenges are yet to be met. These are, fast eroding gene pool, fast population build up, shrinking land and other natural resources, serious production constraints, biotic and abiotic constraints and huge post harvest losses. Further, in the era of globalisation, our produce has to be of international quality and globally competitive. Our future expansion of horticulture has to be in arid and semi arid areas and on under utilized horticultural crops.

While the impact of green revolution in India was felt mainly in assured irrigation areas, horticultural crop production has brought prosperity even in arid and semi arid areas. Horticulture is no longer a leisurely avocation and is fast assuming position of a vibrant commercial venture. Nature has placed India in a state of advantage and it is now on us horticulturists to work towards ushering in a **GOLDEN REVOLUTION** in years to come in India.

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Eroductio Co strai ts a d Ma ageme t i Ma go

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India produces mango in an area of 1.23 million hectares with an annual production of 19.2 million tonnes, which contributes 54.0% of the world production. Yet, India ranks sixth in terms of productivity and far behind in terms of export of fresh fruits which is only 0.02 percent of the total mango production.

The various production constraints which affect quality mango production starts from selection of variety to cultivation practices till harvest. This paper briefly discusses the various production problems and strategies to overcome such problems in an integrated approach, ultimately aiming for quality mango production.

Soil

a. Salinity and Sodicity

Salinity and sodicity are the soil conditions that mainly occur under Indian conditions in arid and semi-arid regions. The area under mangoes in Punjab is fast declining due to increase in soluble salts of the soil. According to Bhambota *et al.,* (1963), high concentration of all the three sodium salts viz., chloride, sulphate and carbonate had injurious effects on the leaves and plants of Langra' mango. Samra, (1985) studied the performance and nutrient status in foliage of Dashehari, Langra and Chousa cultivars of mango in relation to soil and irrigation water sodicity. He reported that scorching of old leaves which first appear on tips and margins of leaves was due to sodium accumulation either by soil or irrigation water sodicity.

To over come soil salinity, saline tolerant root stocks can be very well used. Certain saline tolerant root stocks are Kurukan, Moovandan, Nekkare and 13-1 (Israel).

b. Alkalinity

Alkalinity is injurious especially to young plants and they exhibit symptoms of burning. In hilly terrains, in the soft rocky areas of West Coast, performance of trees are highly erratic. Deep black cotton soils are generally unsuitable. Trees growing in light sand must be fertilized periodically for satisfactory growth and fruit production.

c. Drainage

Mango trees tolerate some flooding or wet conditions only for a short period. Prolonged stagnation lead to leaf wilting, desiccation, stem dieback, reduced growth and tree death. Trees under water stagnated conditions remain unhealthy and chlorotic. Vegetative, flowering and fruiting will be adversely affected. Hence, moderately sloping site are preferred to prevent water logging.

d. Suitable soil conditions

Mangoes are well adapted to many soil types (light sandy loams to red and clay soils). Though it comes up well in all the soil conditions, it is highly successful under red loam soil conditions. Slightly acidic soils or soils with a pH of 6.5 to 7.5 is preferred.

Soils with appreciable quality of gravel or white stone pebbles may be considered good for mango growing if soil conditions are not very alkaline or saline.

Deep rich soils give the best production and fruit quality. Deep soils without impermeable layers permits the development of deep taproot which helps in drought tolerance and wind resistance. Well drained deep red sandy loams add colour and luster to the skin of fruits.

Climate

Mango though adapted to varied climatic conditions, it is highly productive under tropics and lowlands of subtropics. Areas with bright sunny days and relatively low humidity during flowering period are ideal for mango cultivation.

Cloudy weather and increased humidity also encourages greater incidence of pests and diseases. This also interferes with the activity of pollinating insects thereby affecting the fruit set greatly.

a. Altitude

When altitude goes above 1000m MSL, growth and productivity of the crop is poor. The altitude has a definite role at the time of mango flowering. It has been observed that an increase in every 12m altitude, flowering is retarded by four days.

b. Temperature

Mature trees withstand temperature from -3.9^{0}C for a few hours with injury to leaves and small branches. Young trees are, however, killed at -1.7^{0}C to 1.1^{0}C. Flowers and small fruits may be injured if the temperature falls below 4.4^{0}C for a few hours. Optimum growth temperature is 23.9^{0}C to 26.7^{o}C. Low temperature adversely affects the plant growth, besides decreasing the percentage of perfect flowers.

c. Frost and wind

Young plants may be killed by frost seriously at 0^{0}C. Excessive hot winds during summer have an adverse effect both on fruit and foliage. Frequent occurrence of storms may result in huge fruit drop.

Studies on the performance of plants propagated by different methods have shown that in the initial years veneer grafted plants grow faster than that of other methods but in the long run the differences among the methods with respect to growth are non-significant except that the air-layered plants make slightly less growth. But the yield differences are insignificant (AICRP - STF report, 1998).

Canopy Management

a. Training and pruning

In the initial years of mango plantation, removal of side shoots up to the height of 60-90 cm from the ground and leaving 3 to 4 main branches on the trunk at different heights is normally practiced. The lower branches are eliminated by cutting them close to the trunk in order to protect the young plants from excessive heat and moisture and in sub tropical areas against pests and diseases also.

The branches should be properly spaced so that they may not break with the crop load at the bearing stage. Branches growing towards the ground and weak branches are eliminated from the early time. After several years of production, the erect growing branches and some of the laterals are thinned to allow sunlight falling on the lower branches also. This facilitates the growth of new shoots, spraying efficiency, and reduced wind damage, pest and disease incidences, besides improving the quality of fruits.

As mango is evergreen, it requires light pruning only. Under Tamil Nadu conditions normally pruning could be taken up immediately after the harvest is over and may continue until the last week of September. Aged unproductive trees can be pruned moderately or heavily. Severe pruning is also needed to maintain the frame work of plants in high density planting. Need based moderate pruning provide higher fruit yield compared to un-pruned trees.

b. Deblossoming

Young plants obtained through asexual method of propagation usually start flowering immediately after a year of planting even at the nursery stage. This adversely affects the growth and vigour particularly where these plants are allowed to set fruits. This fruiting is on the expense of growth and hinders the formation of strong framework of the plant. There fore, these inflorescences should be nipped off immediately after emergence so that it may not curtail the vegetative growth. De blossoming should be continued till the plant attains the frame work to bear the fruits. Normally within three years' time the plant attains normal size and it is physiologically sound to bear the fruits (Ravir singh and Singh, 1998).

Irrigation Management

a. Water quality and requirement

Mango flourishes equally well under low and heavy rainfall of 250-2500mm annually. With the rainfall of around 750mm and above, irrigation is not essential. Irrigation, however, improves the yield and quality of fruits. For an adult tree, the water requirement is 40-60 litres per day. Quality of irrigation water especially concentration of CO_3 and HCO_3 ions, influence the availability and mobility of nutrients and hence mineral composition of the foliage. Like Na and Ca, concentrations of P, Mn and Fe whose availability is sensitive to quality, especially CO_3 and HCO_3 concentration of irrigation water were also high in old as compared to young leaves. Soil EC should be less than 1 for better growth and productivity.

b. Irrigation in relation to fruit set, size and quality

The carbohydrate accumulation in mango is accompanied by fruit bud differentiation and at this time there is no active growth. So little or no carbohydrate is utilized by the plant. Irrigation promotes vegetative growth under favourable climatic conditions. It is, therefore, suggested that during fruit bud differentiation period, irrigation of mango plants should be stopped. Otherwise irrigation during this period converts fruit or flower bud into vegetative bud, which ultimately adversely affects the fruit yield. During fruit development period, under hot and dry climate, irrigation checks the drop of immature fruits. The moisture deficit in soil brings early maturity to fruits. So regular and normal irrigation to plants during fruit development and maturity period improves the quality of fruits.

Flowering and Fruit set

In mango, flowering and fruit set pose a major problem in its productivity. The total number of flowers in a panicle may vary from 1000 to 6000 depending on the variety. The sex ratio is a varietal feature and this is also greatly influenced by the environment. The normal sex ratio is 3:1 of perfect and male flowers. The proportion of perfect flowers in a cultivar becomes critical for optimum fruit set only when it drops down as low as one per cent. In nature, more than 50 per cent of the flowers do not receive any pollen (Iyer and Degani, 1997).

Absence of rain during the flower initiation and flowering is a pre-requisite for the selection of area for mango. Rains at flower initiation time extends the vegetative phase. Rains during flowering not only washes away the pollen but also encourages the incidence of hoppers. Mealy bugs and diseases like powdery mildew and anthracnose are sometimes damage the crop completely. Cloudy weather and increased humidity also encourages greater incidence of insect pests and diseases. This also interferes with the activity of pollinating insects, which in-turn affects the fruit set. If high temperature, rainfall, humidity persists through out the year, there will be no distinct phases of vegetative growth and flowering in mango and bearing will be poor. In high rainfall areas stone weevil is also a major problem.

a. Use of growth regulators

Auxins like NAA, 2,4-D and 2, 4, 5 -T found to check the flower and fruit drop and increased yields were obtained. These chemicals have the antagonizing effect against the endogenous growth hormones such as ethylene and ABA.

Role of growth regulators in alleviating flowering and fruit setting problems are presented in table.

Growth regulator	Concentration	Stage of spray	Results
NAA	20 ppm	At flowering	Optimum fruit set
NAA and 2,4-D	25 ppm,30 ppm	At flowering	Check fruit drop
2,4-D	5,10 ppm	At flowering	Check fruit drop
2,4-D	Less than 20 ppm	At flowering	Check fruit drop
NAA	50 ppm	At flowering	Check fruit drop
2,4-D	10 ppm	At flowering	Check fruit drop
NAA	40 ppm	Mustard stage	Check fruit drop
NAA	20 ppm	During October and de blossoming once at bud burst	Malformation reduced
NAA or 2,4-D	20 ppm	At pea stage	Control of fruit drop
Alar	100 ppm	At pea stage	Control of fruit drop

b. Use of paclobutrazol

Paclobutrazol, an anti-gibbrellin has profound effect on increasing the fruitset, besides giving better fruit size and quality. Paclobutrazol (cultar) should be used in bearing trees and the dose varies from 1ml to 10 ml based on the canopy spread. Normally paclobutrazol is applied 90 days ahead of flower opening. Required quantity of paclobutrazol is dissolved in 10-15 litres of water and drenched in holes at 8-10 places in circle half way of canopy spread. The application of cultar through soil @ 5 or 10 ml during July-August has reduced the vegetative growth, induced 3-4 weeks early, profuse flowering, regular and higher yield every year than the control trees. In case of " Alphonso" at Vengurla, a regular yield which was 2-8 times more than the control was obtained with this treatment, which also induced 75 to 80 per cent new shoot growth in the fruited shoots (AICRP - STF Report, 1998).

Paclobutrazol treated trees are expected to produce good crops every year and the residual effect persists at least for 3-4 years. Hence, it is advised to follow proper nutrient management, irrigation and integrated insect pest and disease management. The recommended doses of fertilizer doses should be doubled along with double dose of organic manures. Potassium nitrate sprays have added effects. Before applying ' Cultar' it is essential that the field should be moistened with irrigation for proper spread and uptake of the chemicals.

Nutrition

Nutrition of perennial fruit trees like mango was not given due attention in the past. In the recent years, however, attention is being given on nutrition for increasing the productivity of mango.

Mango responds well to N,P,K,Ca,Mg and micronutrients viz., Zn,B,Cu and Mo. Any of the above nutrients may directly or indirectly affect the health of the tree. Sen *et al.*(1943) reported that nutritional deficiency, particularly of N may lead to irregular bearing. Rao and Mukherjee (1989) reported that positive correlations were observed between yield, leaf and soil N and P. Leaf N, concentrations were generally low, and many orchards were in the deficient (%N) and severely deficient (%N) categories.

Soil deficiencies of micronutrients are also common in mango. Mallik and Singh (1959) indicated that Mn, Zn, B, Cu and Mg are indispensable for healthy growth of mango. It is important to realize that the appearance of visual deficiency symptoms indicate an advanced stage of inadequate nutrition. Historically, nutrient deficiency is realised only based on visual symptoms with out correlating with leaf and soil analyses. The non-quantitative approach compelled to develop techniques of tissue and soil analyses for determining nutritional requirements on a proactive as well as scientific base.

Certain important nutrients used to overcome the production problems in mango are given below

Nutrient	Concentration	Remarks
KNO_3	1-2%	Flowering takes place in 5-8 months old shoot
KNO_3	2%	Flower induction 100%
KNO_3 + $N_2H_2PO_4$	2% + 0.6%	Fruit size and quality improvement.
$ZnSO_4$	0.2% to 0.8%	Increased length of panicles and retention of flowers and fruits
Boric acid or Borax	0.1% to 0.2	Increased the flower and fruit quality in Langra
$ZnSO_4$ + Boric acid	0.5% + 0.1%	Increased flowering, fruit size, TSS and ascorbic acid
$ZnSO_4$ + Boric acid	0.5% + 0.1%	Increased fruit number per panicle
Urea	2%	Shortened the span of flowering to 5-7 days, increased yield, TSS and total sugars
Super Phosphate	0.5%	Increased panicle length, increased bisexual flowers, increased flowering
Urea + Super Phosphate	2% + 0.5%	Increased flowering, terminal shoot length, size of leaves
Urea + NAA	2% followed by20 ppm	Increased number of flowers per panicle and fruit set
Urea + NAA	1% followed by20 ppm	Increased fruit retention

Physiological Disorders

It is a well known fact that physiological disorders are major constraints in mango especially under northern parts of the country. The major disorders and the remedies are given below.

Disorders	Remedy
Fruit drop Natural drop increased up to marble stage, pin head, post setting, June drop, embryo abortion, climatic factors and water imbalance	Use auxin sprays before flowering and at fruit set, use of Zinc sulphate as basal and foliar, Alar 100 ppm or NAA 100 ppm
Alternate bearing/Biennial bearing / Irregular bearing Heavy crop in one year followed by lean crop or no crop in the next year	Planting regular bearing varieties, following regular integrated nutrient management, use of paclobutrazol. Moderate pruning to allow sunlight to enter in to the canopy.
Spongy tissue Fruit pulp remains unripe because of unhydrolysed starch due to histological and biochemical disturbances caused by heat in the pulp of a mature fruit at pre and post harvest stage. A non edible sour patch develop in the mesocarp.	Mulching the basins, cover cropping in- between rows, irrigation, integrated nutrient management. Use of calcium nitrate as nitrogen source and for potash use of K_2O and P_2O_5. Use of windbreak. The break down tissue had low total carotene, sugars, sucrose, sugar:acid ratio, K,Ca,Na and higher acidity.
Malformation Vegetative and flower buds mixed or alternated and no fruit set	Integrated approaches like proper nutrient management, irrigation, and integrated pest and disease management. Cover cropping/intercropping, mulching, use of growth promoters like auxins
Black tip Depressed spot of yellowing tissues at the distal end of the fruit, which gradually increases in size and becomes brown and finally black. The growth of the fruit is almost at a standstill and the fruit becomes soft after premature ripening . Such fruit never reach full maturity and drop earlier	a) Borax 0.2% spray before flowering, during flowering and after fruit set. b) Use of 0.8% sodium hydroxide at fruit set and after 4th week c) Brick kiln avoided at least for a distance of 1.75km East and West, 0.75 km North and South d) Use of wind break, cover crop and mulching e) Avoid operation of chimney between the period of fruit set and harvest. If operated, height of chimney should be around 13-16m.
Scorching of leaves Development of brick red colour from the tip of the leaves extending inside the leaf lamina, drying and subsequent collapsing of the tissue. New leaves do not exhibit any such deformities. Almost all the leaves get affected during winter. Symptoms resemble K deficiency	Chlorine injury especially in young plants. Avoid irrigation with water containing chlorides. Under rainfed cultivation, chloride injury is less noticed. The chloride toxicity reduces K content in leaves and so use of potassium sulphate for K nutrition instead of potassium chloride. Avoid water having higher levels of chloride
Internal necrosisWhen the fruit attains full size the lower portion of the fruit becomes brown in colour and the internal tissue becomes soft. Such fruits split vertically and internal tissue show rotting and brown liquid oozes out.	Spray borax 0.3% at fruit set followed by two more sprays at 15 days interval.
Clustering in mangoFruit lets at tips of panicles , which do not grow beyond pea or marble stage and finally drop. The fruit contains no seeds due to lack of pollen and subsequently pollination and fertilization.	Introduction of beehives, use of insecticides at the time of full bloom should be avoided which may kill the pollinators. Top working with other varieties, spraying of 300 ppm of NAA during October-November.

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Co strai ts i Exportable Ba a a Eroductio : Natio al a d 1 ter atio al Eerspectives

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Bananas and plantain are very important fruit crops in the tropical world. They are grown largely by small holders and play a major role in food security and income generation for millions of the region's rural poor worldwide. In terms of gross value of production, banana is the developing world's fourth most important food crop after rice, wheat and maize and as a fruit, it ranks first. More than 100 million tonnes of bananas are produced every year in 120 countries in over 10 million hectares. Only about 13 per cent of the world's banana production is exported and 87 per cent is consumed where they are produced, indicating, that banana plays a vital role as source of food and income in developing countries. Banana constitutes a major staple food for millions of people and provides a valued source of income through local and international trade.

Production statistics in 2004 show that banana is an important crop in the three major regions namely Asia, Latin America and Africa. Most of the export bananas produced are from Latin America. In contrast, bananas produced in Africa and Asia Pacific regions are consumed locally revealing the importance of banana as a major component of diet.

World's Top 10 Banana Producers (2004)

Top 10 countries	Production (MT)		% of total world production
	Bananas	Plantains	
India	16.82	0.00	16.55
Uganda	0.62	10.00	10.44
Brazil	6.59	0.00	6.49
Ecuador	5.90	0.65	6.45
China	6.22	0.00	6.12
Philippines	5.50	0.00	5.41
Colombia	1.55	2.95	4.43
Indonesia	4.40	0.00	4.33
Rwanda	0.00	2.47	2.43
Ghana	0.01	2.38	35.01
Rest of the world	21.38	14.21	

India topped the list with 16.55 metric tonnes whereas the Philippines with a total production of 5.41 metric tonnes came in 6th after Uganda, Brazil, Ecuador and China. Except for the Philippines and the three Latin American countries, most of the leading banana producing countries grow banana for local consumption.

India with the production of 16 million tonnes of bananas annually, provides livelihood security to millions of people in production, trade and processing. The fruit contributes more than 2.8% to GDP of agriculture in India and 31% of the total food production. However the efficiency of banana supply chain in the country is not even a patch on the Indian manufacturing supply chain, resulting into high wastages (30%), high retail to farm gate ratio (1.8) and high mark up percentage i.e. prices paid by the consumers (300%) – one of the highest in the world. In addition to this, lack of particular varieties which are liked by Indian Diasporas in gulf and high landed prices are some of the few reasons for meager export volumes.

Export Standards

- Whole, firm, sound, clean, free of any visible foreign matter, free of bruising.
- Free of pests affecting the general appearance of produce
- With the stalk intact, without bending, fungal damage or desiccation
- With pistils removed
- Free of malformation or abnormal curvature of the fingers
- Free of damage caused by low temperature
- Free of any foreign smell and / or taste
- For Robusta : Fruit length ->21 cm ; Circumference -> 14 cm

Production Constraints

Indian banana production is peasantry in nature. Systems of cultivation varies with soil, irrigation facilities and topography of the land. Can India export bananas? You have to consider many things before answering.

Varieties

Cavendish group of bananas like Grand Naine, Williams, Poyo, Valery form the basis of export. In India, the choice of variety is market driven. Polyclonal and small farming system is suitable only for meeting the domestic needs where less importance is given for the cosmetic qualities of the fruit. It is rare to see contiguous areas of one variety. Polyclonal system is a handicap for export.

Varieties suitable for export should be identified and grown in larger extent, so that volume required in export can be met with.

System of Cultivation

In banana exporting countries in Central America, West Indies and Western Africa, the plantation size is quite large ranging from 5000 to 10000 hectares. Under such company cultivation, systematic production technologies can be adopted in a more scientific basis. Necessary infrastructure facilities like wire rope for transporting the bunches harvested to the yard where subsequent post harvest handling cleaning, grading, washing, packing etc. are taking place.

With small farming system, development of such facilities may not be viable.

Cost of Production

Banana plantation meant for export are generally located in soils of unsurpassed richness in fertility. Most of the Latin American countries and African countries closer to equator receives well distributed rain round the year. Thus, banana are rainfed and do not receive supplementary irrigation. Fertilizer need is assessed based on leaf analysis, as the plantation life varies from 8-15 years. The individual clump consists of 3 to 4 plants of varying age. Production system is oriented towards maintaining "Clump Health Management". Thus, the cost of production of export-quality banana is much cheaper than what we produce for local market.

Disease Management

Well distributed rainfall, high humidity and optimal temperature of 28-32^{0}C not only favours growth banana, but also development and spread of Sigatoka diseases. As the disease defoliates extensively, the fruit development would be drastically affected. Poor fruit filling, peel-splitting and premature ripening are the associated maladies. Exportable yield banana, thus, depends on efficient control of Sigatoka diseases.

Generally, fungicidal spray to control the leaf spot disease is done with specially designed aircrafts which can cover 30,000 hectares within 3 hours. Depending on the intensity of the disease 30-50 rounds of aerial spraying is given. Sufficient number of functional leaves are maintained (not less than 15 at flowering and 9 at harvest).

In India, the Sigatoka disease is seasonal, usually appears from November to March. Only 2 to 3 sprays are given to check the spread. Economic status of the farmer prohibits spraying more number of sprays.

Assessment of Harvestable Maturity

Bunches are harvested at appropriate maturity which is very much necessary for export. Uniform sized fruits can be obtained only through scientific methods fruit filling. Based on "had-units", the harvestable maturity is assessed, as the temperature varies with the season.

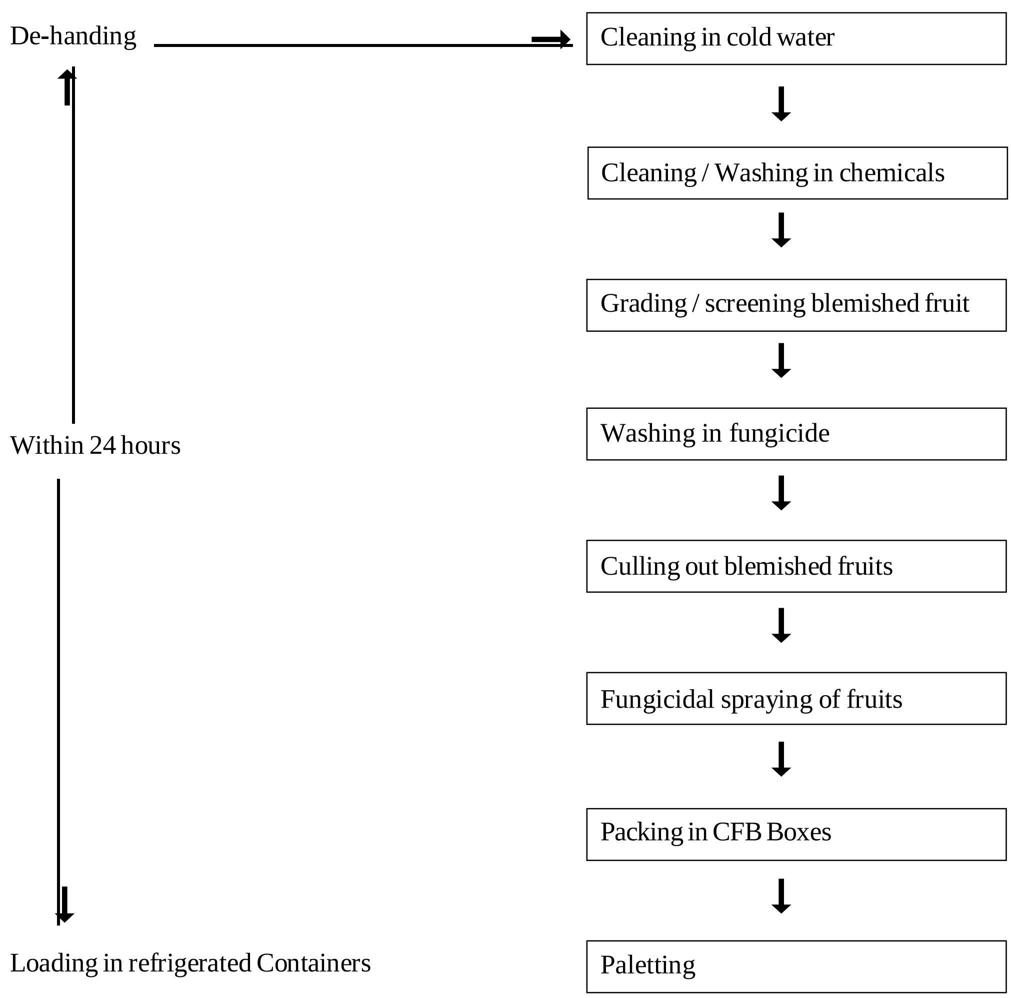
Under the Indian conditions, it becomes difficult to maintain required number of green leaves, as the produce is meant for local market only.

Post harvest handling

A banana bunch undergoes several post harvest processes before being packed in CFB boxes for export.

Harvested bunches are wrapped with sponge sheet and sent to the packing yard through rope way to avoid damage to the fruits.

PACKING YARD



Transporting

Good road from plantation to port is very essential to reduce damage in transit. This is a big problem under Indian conditions.

Big banana exporting companies like Dole, Chiquitas, Fytees etc. have refrigerated ships called "Banana Ships" where temperature and humidity are monitored well. Ships reach the destination without delay.

These companies have played a major role in the production and development of international trade in bananas. Years of hard extension work among the farmers in the Caribbean and African countries convincing the respective governments, developing right varieties and protocols, perfecting and developing post-harvest technology have paid rich dividends both to the companies and have also brought some prosperity among the farmers. The farmers are happy as they get payment every week round the year unlike in other crops, which are seasonal with no assured markets and returns. Another advantage is that the protocols of de-handing, grading, packing, transport are all standardized and are in position. These companies are financially very sound, and have good standing and credibility indelibly in the market. They also have a very good marketing network in the importing countries which itself is a great asset.

Supply-Chain System:

Exporting companies have well organized system of supplying fruit to different importing countries. They have well knit system of assessing the demand and other trading intelligence. Survival of banana export trade depends on continuous supply and maintenance high level quality standards.

What India can do to enter into export trade of bananas :

India is yet to develop its infrastructure facilities for export of bananas. The following points have to be considered :

- **Choice of suitable variety.** Besides Cavendish clones, India can very well think of exporting other varieties like Ney Poovan, Red banana, Pisang Mass and Rasthali. As a first step, India should take efforts to create awareness about many varieties grown India.
- Organising farmers to grow chosen variety in one compact blocks of not less than 100 hectares.
- Good extension work to educate the farmers on various production protocols for producing fruits of exportable standard.
- Creation of common facilities for every hectares, like cleaning and packing facilities including refrigerated containers.
- Training labourers on various post-harvest handling upto packing in CFB boxes. Human resource development should be a continuous process.
- Co-operative system of cultivation for export, as practiced in Thailand by small farmers needs to be adopted with modification.
- Continuous assessment of different importing markets, knowledge about season-wise quantity requirements.
- Monitoring agencies for periodical monitoring of quality by trained technicians should be set up.
- Organic banana export can be considered.
- Designing banana ships.

Reducing final cost of production to be more competitive in export trade.

Eroductio Eroblems i Grapes a d their Ma ageme t

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Grape is one of the important fruit crops, both in the temperate and tropical parts of the world. It is believed that it might have been introduced into India during 19th century. At present, the principal grape growing states are Andhra Pradesh, Karnataka, Maharastra and Tamil Nadu in south India and Punjab, Haryana and U.P. in North India (Chadha and Shikhamany, 1999).

Based on the climatic conditions, these grape growing areas can be divided as follows.

1. Subtropical conditions of north India where the winter temperature reaches near freezing point and vines undergo dormancy where it is possible to harvest only one crop (Summer crop) in a year.
2. The tropical plains of south India where the winter temperature is mild and vines do not undergo any dormancy and hence, it is possible to harvest two crops in a year and five crops in two years.

Climatic constraints

The amount of rainfall and its distribution has pronounced effect on grape cultivation in India. Area, with annual rainfall not more than 900mm, seems to be ideal. More than the amount of rainfall received during a year, the number of rainy days in a year and the occurrence of rains in relation to the stage of growth of vine is important. Distribution of rainfall determines chiefly the time of pruning and the cropping pattern in different grape-growing regions of India. Humidity associated with rains during flowering is favourable for the spread of downy mildew. Continuous drizzling for more than 48 hours at the time of flowering can devastate the crop by the infection of downy mildew on inflorescences. Rainfall, to an extent of 10mm in a day or in consecutive two days during berry ripening, particularly in *vinifera* grapes, can ruin the crop by berry cracking and rotting. Rains, associated with cloudy weather during the period of fruit-bud differentiation, can hamper the initiation of floral primordium. Rainfall associated with cold weather, at the time of forward pruning, reduces the budbreak and consequently the yield.

Bloom and fruit set takes place in January - February for summer crop while in July - August for winter crop in Tamil Nadu. January - February is relatively a dry period with almost no rainfall, but July - August is a period of good rainfall. High rainfall associated with high humidity and reduced temperature is highly congenial for the incidence and spread of mildew diseases. Therefore, plant protection during this period is very critical to control the mildew diseases.

Atmospheric temperature during the growth and fruiting season has definite bearing on the fruiting and fruit quality of grape. Temperature ranging from 15 - $35^{o}C$ is ideal for shoot growth and normal physiological processes of the grapevine. The optimum temperature is between 25^{o} and $30^{o}C$. High temperatures reduce photosynthesis by the inactivation of enzymes and closure of stomata. Due to reduced photosynthesis, shoot growth also retards when the temperature exceeds $40^{o}C$. Under high temperature conditions, respiration rate increases at faster rate than photosynthesis and the reserves are spent more on respiration, depriving the growing shoots of the reserves.

Light is also an important factor in determining the fruitfulness of buds in grapevine. Though grapevine is not classified as a long day plant, for floral induction, its bud fruitfulness is generally higher under long days than short days.

Importance of light over temperature in the fruitfulness of the buds can be explained by shading of grapevines under field conditions, reducing the light interception in the vine canopy without reducing the temperature. 'Sun canes' were more fruitful than shade canes in 'Thompson Seedless' and 'Pinot Noir' varieties.

The mean cluster size was also more on sun canes as compared to shade canes.

High humidity is generally associated with rainfall. High humidity (more than 50 per cent) during the period commencing from 30 days until 110 days after forward pruning encourages the incidence and spread of fungal diseases.

Hot winds can increase the rate of transpiration and consequently desiccate the vine. Shoot breakage is common in April and May due to strong winds in peninsular India. High wind velocity may disturb training and rapidly spread the diseases.

Soil constraints

The soil temperature will be high in dark soils than light colored soils. Water permeability is high in red soils while it is poor in bluish grey soils.

Soil drainage is very important from the point of air movement and active root growth. Hence, well-drained soils are very important. A clay-mixed sand or a sand-mixed clay is beneficial for vines.

Winkler *et al.* (1974) mentioned that grapes are being grown successfully on soils less than 2 feet deep, where good irrigation water is available and is carefully managed. Root activity studies using P^{32} by Rao *et al.* (1971) have revealed that the concentration of active feeder roots is more at a depth of 22.5cm in Anab-e-Shahi under Coimbatore (India) conditions. Dasarathi and Afzal-un-nisa (1972) found that the active feeder roots in the same variety are located at a depth of 30-37.5cm under Hyderabad (India) conditions.

Considering all the varieties together and findings from many studies, it can be inferred that grapes can be grown successfully not only over a fairly wide range of soil pH (4.0-9.5), but they can also thrive well and produce normally at such high alkaline conditions, which are normally harmful for other plants.

Production constraints

Some of the major production constraints are

a. Problems during ripening :
    1. long ripening period
    2. rain during ripening period
    3. simultaneous ripening period
b. High cost of overhead trellis
c. Root stocks - Unavailability /
d. Drought : Drought tolerant root stocks

116 Richter, 140 Ruggeri	- Highly tolerant
Panlsen, SO_4 and 99 Richter	- Tolerant
Rupestris due hot (St. George)	- Less tolerant
Riparia Glorie	- Susceptible

Management of saline-alkali soils

The problem of salinity is on the increase every year. The problem has assumed alarming proportions in states like Punjab, Haryanana, Maharastra and North Karnataka. Chloride is found to be the most toxic anion among salts. A highly significant correlation is noticed between leaf scorch and chloride content of leaves and soil.

Leaching of salts by heavy applications of water to soil is the most effective and economical way to overcome the soil salinity. Gypsum application was found to remove nearly ten times as much salts from the system as in the untreated soil.

Saline tolerant rootstocks: Rootstocks play a great role in management of salts. Level of chloride in petioles of Thompson Seedless vines grafted on Ramsay (Salt Creek) and 101-14 (Riparia x Rupestris hybrid) was about 75 per cent lower than that of own rooted vines while 'Dogridge'and 1613 induced reduction of about 50 per cent. St. George and 99R were even better than Ramsay in limiting chlorides.

Dormancy related problems

Dormancy breaking (or) bud breaking is the basic requirement for initiation of new growth by vines. Time, duration and extent of budbreak decide the earliness and production potential of a variety.

Reasons for poor bud-break (or) dormancy

1. Cane maturity.
2. Lack of chilling of buds.
3. Reducing temperatures after pruning.
4. High degree of apical dominance.

Attempts made on bud breaking

Variety	Treatment applied and dose	Results	Authority
Tas -A-Ganesh	Dorbreak (Hydrogen Cyanamide 50%) @ 20 ml/lit	Maximum budbreak (99.20%) and highest yield (10.82 kg/vine) were obtained against 24.40% and 5.28 kg/vine in control. Duration of bud break and number of days required for bud break were also reduced from 12.19 days (in control) to 2.20 days and 20.59 days (in control) to 8.34 days.	Somkuwar et al. (1999)
Sharad Seedless	'Dodbreak'40 ml/lit	Bud break increased from 23.2% (in control) to 92.0%. Duration was reduced from 7.86 days (in control) to 2.72 days (30 ml/lit treatment). Time requirement was also reduced from 19.5 days (in control) to 11 days. (30 ml/lit treatment). Yield increased from 5.27 kg/vine (in control) to 9.12 kg/vine (30 ml lit treatment).	-do-
'Sonaka'	'Dorbreak'40 ml/lit	Bud break increased from 38.4% (in control) to 92.0%. Duration of bud break reduced from 7.71 days (in control) to 4.52 days (20 ml/lit treatment). Time duration was also reduced from 18.61 days (in control) to 2.64 days (30 ml/lit treatment). Yield increased to 6.95 kg/vine against 3.74 kg/vine in control	-do-
Bhokri	Thiourea 2% 8 sprays @ 4 days interval during 1st week of January	Bud break was advanced by 15 days and per cent bud break was also increased from 51.2 (in control) to 66.7%	Singh (1999)
Pusa Seedless	Ethephon, Thiourea, Sodium azide, 'Dorbreak'	Dorbreak (1.5%) hastened maturity by 15 days, thiourea (2 and 3%) hastened maturity by 5 days. Budsprouting and flowering were also advanced by these treatments	Pramanick et al. (2001)

Quality improvement

Variety	Treatment applied and dose	Results	Authority
Tas -A-Ganesh on Dogridge rootstock	Gibberllic acid with 'Vinin	Bunch weight and total number of berries / bunch did not differ significantly. Berry characters like 50 berry weight, berry diameter and berry length increased significantly	Ramteke et al. (1999)
	Dipping in 10 ppm 4 CPA (or) 2 pm CPPU @ 6 mm size & berry softening and GA @ 25 ppm @ 3 & 6 mm size	The pedicel thickness increased, freshness of grapes retained and berry drop reduced	
	GA treatment @ 10 ppm at 5 leaf stage, 15 ppm @ 8 leaf stage, 40 ppm @ 30-50% bloom, carbaryl 1000 ppm @ 90% bloom	It produced loose clusters which eliminated manual thinning.	
	Berry thinning 40% and gridling @ fruit set & 10 days after	Cluster weight was slightly depressed by berry thinning and girdling. Then, weight of berry increased & shot berries decreased. Fruit quality aspects improved significantly	Dhillon and Bindra (1999)

Variety	Treatment applied and dose	Results	Authority
Muscat	20% thinning at pea stage, removal of cluster tip by 3.5 to 4.0 cm at cumbu stage and dipping the clusters in solution containing brassinosteroid 0.5 ppm and GA3 25 ppm at 4-5 mm diameter of berries	Quality parameters like TSS, total sugars, reducing sugars, non-reducing sugars and sugar-acid ratio were improved	Velu (2001)

Cheema *et al.* (2003) conducted studies on reducing the crop load of Perlette grapevines to 50 per cent by cluster or berry thinning and exposing the fruit to direct sunlight to study their effect on fruit quality. Berry thinning was more effective than cluster thinning in increasing berry size, total soluble solids and reduction in juice acidity and extent of short-berries in the cluster. Exposing the clusters to direct sunlight through canopy management had some effect in improving the fruit quality. Crop regulation or berry thinning treatments had no effect on incidence of anthracnose or powdery mildew diseases.

Nutritional disorders and other maladies

i. Leaf curl

Inward curling of mature leaves of normal size is due to deficiency of K and high 'N' levels which results in temporary water deficit in the plants caused by excessive transpiration due to inadequate potassium to regulate the stomatal closure.

ii. Leaf chlorosis

No definite trend in the potassium content in relation to marginal chlorosis and in magnesium content in relation to interveinal chlorosis was observed. K, Ca and Mg contents were low in all the chlorotic samples.

iii. Pink berries in Thompson Seedless

Large diurnal variation in temperature that occurred during the period of ripening was responsible. The day temperatures were ~39ºC while the night temperature were ~10ºC during February. Berry softening during February led to more pink berries. Calcium sprays given after berry softening also lead to pink berries.

1. Prune the vines either in the last week of October or first week of November.
2. Avoid soil moisture stress from berry softening until 10 days prior to harvest.
3. Give adequate dose of potash during 30 days prior to berry softening.
4. Treat the clusters with BA at 10 ppm at berry softening to minimize the loss of chlorophyll from the bunches (Remteke *et al.,* 1998).

iv. Bunch necrosis

Bunch necrossis is a common disorder of Tas-A Ganesh resulting in a considerable loss in yield. The disorder is noticed at verasion stage. Sharma *et al.* (2000) found that impaired translocation of Ca and Mg into the petioles and rachis of vines resulted in necrosis.

Pests

Nematode and phylloxera populations in soil is also of special significance in grape cultivation. However, phylloxera is not a problem in grape-growing soils of India, whereas problems with nematodes have been experienced. *Ganoderma*, a basidiomycete fungus in the soil, can also infect the grape roots at the collar region and has the potential to kill the vines (Teliz, 1979). This fungus was also found to infect Anab-e-Shahi grape in Hyderabad region of India (Satyanarayana, 1981). Besides, the heavy spray schedules also lead to residual toxicity

Nematodes

Nematodes are a serious threat to viticulture. It is better to manage them by using nematode resistant rootstocks like 1613, Dog Ridge , Salt Creek (Ramsay), Harmony and Freedom.

Phylloxera

Rootstocks play a great role in the resistance to *Phylloxera*. Resistant rootstocks reported are St. George, Ax R1, 1202, 99-R, 3306, 3309, Riparia Glorie, Teleki 5-A, Selection Oppenheim No.4.

Post-harvest problems

i. Sulphur injury

Sawant and Sawant (1999) conducted a study to know the effect of essential oils on post-harvest pathogens with a view to find alternatives to $Na_2S_2O_5$ which is presently used in export packings and causes SO_2 injury to grapes. The results indicated no differences in fungal growth in various treatments and control.

ii. Decay of grapes in storage

Cladosporium sphaerospermum and *Alternaria alternata* were found to cause decay of berries during cold storage. Botrytis was not associated with berry rot in cold storage. Dual release 'Grape-guard' containing 2.3 g of sodium bisulphite was adequate. At higher doses of sodium bisulphite (3.5g), So_2 injury was observed at the pedicel end. Grapes, sprayed with Benomyl @ 0.1 per cent 20 days prior to harvest and packed with dual release grape -guard containing 2.3 g of sodium bisulphite, showed least rotting during 8 days of storage at room temperature after 30 days of cold storage.

iii. Desiccation of grapes in storage

Desiccation as measured by the physiological loss in weight (PLW) was reduced by cutting the bunch stalk 1 cm above the knot and pre-cooling the grapes within four hours after harvest. Shelf life of grapes after 30 days of cold storage increased and berry rotting decreased with dipping the bunches in one per cent calcium nitrate solution on 90th day after pruning.

Grapes, wrapped in absorbent tissue paper and low density polyliner (Europe make), remained fresh in the shelf until the third day after 30 days of cold storage. Berry rotting was also reduced by the combination of these wrapping material.

Product diversification

Nearly 90% of the produce in India is consumed by fresh fruit industry. This results in lot of post-harvest losses and slump in prices which discourages the expansion of area (or) cultivation in unconventional areas. In developed countries, 90% of the produce is taken by wine industry wherein large differences in prices are not witnessed. Market glut is not noticed. Hence, is has become necessary to develop new products to sustain the prosperity of the industry.

Ravikumar *et al.* (2005) conducted an experiment in grapes to standardize the optimum pH and TSS levels for quality wine production. Grape bunches of cultivars 'Muscat', 'Bangalore Blue' 'Sharad Seedless', 'Thompson Seedless' and 'Tas-a-Ganesh' harvested during March-April, 2004, were used for this study. Results on wine quality parameters revealed that the wine from 'Muscat' was ranked as 'excellent', 'Bangalore Blue' as 'Commercially acceptable', 'Sharad Seedless' as 'Defecient wine', 'Thompson Seedless' as 'Good' and 'Tas-a-Ganesh' as 'Poor and objectionable'. Browning, a problem in white wine, was noticed in both the cultivars 'Thompson Seedless' and 'Tas-a-Ganesh', but that was controlled in 'Thompson Seedless' at pH 3.0 and TSS 20^{o}brix but not in 'Tas-a-Ganesh'.

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Ma ageme t o(Eroductio Co strai ts i Citrus

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Citrus fruits occupy premier position both in area and production world over and more so in India. In terms of fruit products, no other fruit is as utilized as citrus internationally. Canned and fresh citrus juice, citrus juice concentrates marmalades and their use in jams and jellies makes it as one of the most sought after fruits in the world. Brazil, USA,China, Spain and Mexico are the leading producers of citrus in the world. World production of Citrus kinds was estimated at 108.5 million tonnes from an area of 7.3 million ha during 2004 with an average productivity of 14.72 t /ha (FAO STAT 2004). The area under citrus kinds is estimated at 2,64,500 ha and the production is estimated to be 4.75 million tonnes in India . The average productivity in India works out to just 17.95 t /ha (FAO STAT 2004).The most important commercial citrus cultivars in India are the mandarin (*Citrus reticulata* Blanco), followed by sweet orange (*Citrus sinensis* Osbeck) and acid lime (Citrus aurantifolia Swingle) Commercially, Kinnow mandarin is grown in Punjab, Haryana, Himachal Pradesh, western part of Rajashtan and Uttar Pradesh; Khasi mandarin in north eastern region; Darjeeling mandarin in Darjeeling; Acid lime in Khera district of Gujarat, Akola in Maharashtra, Andhra Pradesh, Southern districts of Tamil Nadu; Nagpur mandarin in Vidarbha region of Maharashtra and adjoining areas of Madhya Pradesh; Mosambi in Marathwada region of Maharashtra; Sathgudi in Andhra Pradesh and Coorg mandarin in Coorg area of Karnataka.

Citrus growers especially in the tropical regions of India face a myriad of problems and more often solutions to these remain elusive. The dire necessity to initiate research programmes intensively on citrus led to the establishment of the Central Research Station at Nagpur in 1985, which was elevated to the status of the National Research Centre for Citrus later. Various research programmes are also being pursued under the All India Co-Ordinated Research project partly financed by ICAR in several centres.

Citrus cultivation today is threatened due to various physiological disorders, fungal, viral and bacterial diseases, pests, nematodes etc. The intensity of these problems varies from region to region impacting seriously the production and quality. While some of the problems are specific to a particular kind (Eg. granulation in Sweet Orange), others are common to many citrus kinds. Among the various production problems, apart from pests and diseases, the following can be considered as important for horticulturists to tackle .

1. Non availability of reliable & virus free planting material
2. Unsuitable rootstocks for specific situations
3. Unfavourable soil conditions and poor water quality leading to physiological disorders
4. Poor nutritional management
5. Physiological problems due to environmental conditions

Management aspects related to these problems are briefly discussed here.

A. Non Availability of reliable and disease free planting material

Lack of quality planting materials propagated from ideal mother trees is major constraint. World over, when newer varieties have started replacing the older ones, in India, the extension of the area with newer varieties has not progressed. Aged orchards have become more prone to various diseases and hence the planting materials from these orchards are highly unfavourable or unsuitable.

While tissue culture techniques like micrografting and microbudding can be helpful to eliminate systemic diseases, the production of such micro grafted planting materials has not become commercial.

Management strategies would involve use of certified bud woods free from diseases and microbudding or shoot tip grafting techniques. Multiplication of properly disease indexed plants (both root stocks & scions), use of shade nets and insect proof nets as protective covers, adopting newer multiplication techniques like micrografting are the ways to get disease free planting materials.

I. Certified budwood supply program

The following are the steps required to supply certified bud woods for commercial and large scale propagation

1. Establish a foundation block of disease-free trees of all major commercial and non-commercial varieties of citrus
2. Maintain a rigorous program of testing and retesting of foundation trees to assure continued freedom from disease
3. Evaluate the horticultural characteristics of foundation trees to assure trueness-to-type and
4. Develop and maintain blocks for the production and sale of certified bud wood for the production of disease-free citrus nursery trees

II. Micrografting / Shoot tip grafting

The technique of micrografting is now routinely applied to the recovery of Citrus clones from virus diseases. It consists of "in vitro" grafting of an excised shoot tip apex onto *in vitro* raised and decapitated seedlings as rootstock (Navarro *et al* 1981). Applying this technique numerous clones of Clementine, sweet orange, lemon and of other species of Citrus have been recovered from all the virus diseases by various research workers. About 40 % of the apices survive using the above-mentioned technique generally. By dipping the apex and the decapitated seedlings for ten minutes before micrografting in a solution of 6-BAP at 0.5 ppm, the percentage of sprouting increased from 73% to 91%. A survival rate of 63% has been obtained through the lateral micrografting. (Starrantino and Caruso, 1988). From the time of grafting , within couple of months, the newly budded plant will have achieved typical liner size for transplanting into the field or into a container to be grown on to acceptable size for ultimate use. Higher incidence of *Phytophthora* infections in field planting has been reported due to relatively low insertion of the microbud. In India, this technique has been standardized for Nagpur mandarin (Vijayakumari *et al,* 1994).

III. Diagnostics

A range of techniques can be used to detect and identify viruses including symptomatology, electron microscopy, indicator plants, serology and nucleic acid hybridization etc. Each method has certain advantages and disadvantages. Modern serological detection techniques can be highly sensitive to detect known viruses, but are also highly specific, and so reliability may be complicated by the occurrence of a wide degree of serological diversity of a virus. Earlier ELISA tests were employed in detecting the important virus diseases. At present more efficient methods like PCR based diagnostics are available.

IV. Rootstocks for specific situations

Studies taken up on different rootstocks for various citrus kinds have resulted in recommendation of specific

Root stocks for Citrus

Rootstocks	Horticultural performance			Resistance to					
	Yield	Quality	Vigour	Foot Rot	Nematode	Tristeza	Exo-cortis	Salt	Drought
Sour Orange	G	G	M	R	T	HS	T	T	MT
Sweet Orange	G	G	M	HS	HS	Mt	R	S	S
Rough Lemon	G	L	G	S	S	R	R	T	T
Cleopatra mandarin	M	M	M	T	S	R	R	MT	S
Rangpur Lime	G	M	G	MT	S	R	S	R	R
Sweet lime	M	M	G	S	MT	S	S	S	S
Troyer Citrange	M	G	M	MT	T	MT	S	HS	HS
Trifoliate Orange	L	M	L	R	R	R	HS	HS	HS

G-good, M-moderate, L-Low, MT-moderately tolerant, MR-Moderately resistant, S-susceptible, R-resistant, HS-Highly susceptible rootstocks against a particular situation. Unfortunately, even multiplication of those rootstocks in sufficient numbers with assured quality is not available for large-scale propagation in those regions affected with the specific problems. While these root stocks possess the resistance / tolerance attributes, the quality of the produce by using these root stocks may become another problem in certain situations. This has led to the situation at present wherein the plants produced by private nurserymen are procured by majority of the growers as alternate sources for planting materials are lacking. These materials then will continue to be the source of disease inoculum for many more years.

From studies carried out with Valencia' sweet orange trees on Carrizo Citrange or Rough Lemon rootstocks, differential sugar accumulation of citrus fruit from trees on rootstocks of contrasting vigor was found to be influenced by differences in tree water status and the enhancement of sucrose hydrolysis into component hexose sugars via osmotic adjustment. Therefore, inherent rootstock difference affecting plant water relations was proposed as a primary cause of differences in juice quality among citrus rootstocks. (Barry *et al.*, 2004).

B. Soil conditions

Citrus planting across the country is taken up at in soil situations, which are not ideal but actually pose problems to the crop over a period of time. Some of the problems are due to

- shallow soils less than two feet in depth
- to presence of high clay, silt, $CaCO_3$ in sub-soil,
- low organic carbon, available nitrogen, phosphorus low exchangeable Mg
- high $CaCO_3$, salinity and ESP in the surface/ subsurface regions

Soils with clay content of more than 28 % are unsuitable. Deep ploughing of clay soils may lead to hardpan development that restricts root growth. A pH range of 5.5 to 7.5 and EC upto 1.8 ds. m^{-1}, ESP upto 5-10 % and $CaCO_3$ around 10 to 12 % is suitable for most of the citrus kinds. For a review on soil suitability criteria, the reader is referred to Srivastava and Kohli (1997).

C. Water quality and Water management

Citrus plants are also affected by poor water quality and improper and often insufficient irrigation. Poor water management practices compound the problems faced by the plants. Irrigation scheduling based on pan evaporation can save upto 23 % water. Irrigation at 0.8 of open pan evaporation through drips is ideal to increase growth, yield and quality of Nagpur Mandarin. Water containing chlorides less than 200 ppm, EC less than 0.25 mmhos /cm and RSC less than 2.5 me/l and SAR less than 8 is considered safe for irrigation. Microirrigation practices can help to save upto 40 % water and simultaneously improve plant performance.

D. Nutrition

Because of soil and water problems, nutrient availability gets limited. Nutritional disorders especially micronutrient deficiencies are frequently encountered in citrus orchards. Soil tests for pH, phosphorus, calcium, magnesium and copper are useful. Soil test for more readily leached elements, such as N and K may not be useful, since it is difficult to establish the yield responses due to levels of fertilizer elements in soil. Leaf tissue sampling and nutritional norms for mandarins have been standardized.

For Nagpur mandarin cultivar, 6 to 8 month old leaves for Ambia flush and 5 to 7 month old leaves for Mrig flush from any leaf position out of 2nd, 3rd or 4th leaf on a shoot at an height of 1.5 to 1.8 m from the ground and number of leaves as low as 30 covering 2% trees in an orchard will be sufficient to represent the nutrient status. (Srivastava *et al,* 1994). In acid lime 3 to 5 month old leaves were found suitable for leaf sampling. The use of spring flush leaves in Kinnow mandarin under Tarai conditions has been recommended for collection of leaf samples to diagnose the nutrient status.

Problems may also arise due to excess application of nitrogenous fertilizers. Reduction of leaf K content with increased N and vice-versa results in improper balance . A leaf N/K ratio of 2.49 with leaf N of 2.42 % and K as 0.97 % was observed as optimal values for Nagpur mandarin. Micronutrient deficiencies are quite very commonly observed in many citrus orchards. Remedial measures usually consists of foliar spray with the micronutrients that are in deficit. Problems with micronutrient levels will arise when leaf tissues show high values which may be because of chemical residues. Zinc sulphate proved ineffective under calcareous conditions while chelated source like Zn-EDTA @ 50 g per plant was found to be very effective in alleviating Zn deficiency.

Recent research reports indicate that the following fertilizer schedules have given better results (Anon, 2004).

Fertiliser schedule

Crop	N: P_2O_5:K_2O g /tree	Centre
'Khasi' Mandarin	600:400:600 + 7.5 kg neem cake	Tinsukia
Sweet orange	600:325: 450 +7.5 kg	Tirupathi
Acid Lime	800:200:300 g	Tirupathi
	600:300:600 g	Rahuri & Periyakulam

Optimal Leaf Nutrient Concentrations for Mandarin

Nutrient	Coorg Mandarin (Anon, 1980)	Kinnow Mandarin (Chahill *et al*, 1991)	Nagpur Mandarin (Kohli *et al*, 1998)
N (%)	2.91-3.15	2.80	2.2-2.4
P(%)		0.15	0.07-0.10
K (%)	1.51-1.61	1.57	1.18-1.56
Ca(%)			1.32-1.51
Mg(%)	0.32-0.36		0.48-0.67
S(%)		0.34	
Fe (ppm)		103	110-132
Mn(ppm)		38	29-43
Zn(ppm)	62.00		8-15
Cu(ppm)	9.8		18-29
B(ppm)		109	

The problems related to fertigation of citrus under Indian conditions are yet to be studied in detail. The scheduling of major nutrients will depend on the age of the crop, the vigor due to root stock & scion, season, soil conditions etc. All these factors will have to be carefully considered. Information related to fertigation for citrus kinds still remain sketchy. Trials taken up at NRC citrus indicate irrigation scheduling with 70-80% ASM along with 500 :140 : 70 g NPK /plant / year has given good results in Nagpur mandarin.

E. Physiological disorders

Citrus kinds also suffer several physiological disorders, which are due to a combination of factors; mostly nutrient related and adverse environmental conditions. A brief outline of these factors is mentioned here.

1. Fruit cracking

- Two types of cracking noticed in various cultivated of lemon include radial (longitudinal) and transverse. In both form, fruits crack severely down to the core and in extreme cases, there is complete splitting of fruits. Radial type is more common.
- 90% cracked fruits show radial cracks and only 10% exhibit transverse injury.
- Cracking occurred due to increase in moisture content within the tissue due to heavy rain followed by a period of drought. Cracking was more evident when the fruits were at maturity stage.
- Soil moisture fluctuations, infestation by diseases and pests and mechanical injuries can also contribute to its occurrence.

2. Granulation

A. Symptoms

- First reported from California; later reported from many citrus growing countries such as Brazil, South Africa, Egypt, Australia, Vietnam, Japan, Israel, West Indies, India, Thailand.

- Juice sacs comparatively enlarged, giving a flat and insipid taste
- not evident until the fruit is nearly or fully mature
- large sized fruits are more affected.
- fruits develop abnormal shape due to lopsided growth of juice vesicles and resultant bulging of the affected portion.
- affected portion of the pulp assumes a granular texture with low TSS
- with increase in granulation, alcohol insoluble solids like cellulose, pectic substances, hemicelluloses, starch and lignin also increased.
- less extractable juice because most of it turns into gelatinous mass and results in more quantity of rag and thus low pulp / rag ratio

B. Factors

Although specific causes of granulation are still not confirmed many causes have been attributed. Some of the important ones are as follows.

1. Humidity	Humid climate particularly in coastal district favours granulation.
2. Temperature	Low temperature increases the extent of granulation
3. Tree age	Higher in younger trees than in old trees.
4. Tree health	Granulation in case of young trees found to be higher in declining trees than in healthy trees.
5. Tree vigour	Granulation is abundant in fruits produced on old trees which are heavily pruned and produce luxuriant growth.
6. Crop load	Higher incidence of granulation in trees carrying a heavy crop.
7. Fruit size	Incidence of granulation is higher in large sized fruits.
8. Root stock	It gave a marked effect on granulation. Trifoliate orange, rough lemon stocks show higher incidence of granulation whereas in grape fruit granulation incidence is lower.
9. Variety	In California in Valencia late incidence is higher susceptibility. Hamlin, Mosambi, Blood Red, Jaffa and Valencia Orange had higher incidence In India

C. Control measures

1. Irrigation	the amount and frequency of irrigation reduces granulation without affecting quantity, quality of fruit.
2. Lime spray	Lime spray @ 18 – 20 kg in 450 litres of water is effective.
3. Auxin	Sprays of 2,4-D at 12 ppm delay the incidence of granulation in Valencia oranges.
4. Nutritional sprays	$ZnSO_4$ (0.5%) and $CuSO_4$ (0.5%) in a combination spray is effective in checking both the incidence and extent

5. Selection of cultivars which are less prone to granulation should be used.
6. Proper time of harvesting of fruits is very effective

For a thorough review on granulation, the reader may refer to Room Singh (2001)

3. Fruit drop in citrus

In most commercial varieties heavy fruit drop and low fruit set are serious problems. As the period of development of fruit extends to 8 or 9 months, fruits continue to drop at various stages during this period. Even if 4-6% of the flowers normally set it is enough to produce a normal crop. Natural fruit drop occurs as a result of sink-source adjustment by tree to prevent from exhaustion as a result of excessive bearing.

Fruit drop occurs in three stages. Shortly after fruit set, aborted pistils tend to drop. With the onset of summer (May-June) due to desiccating wind, low atmospheric humidity, low soil moisture and high temperature fruit drop can occur (June drop). The third wave of drop occurs just prior to harvest. Some time half developed fruits may drop also (premature drop). The intensity of fruit drop may vary with varieties, climate, soil conditions etc.

Hormonal status in the developing fruit plays a major role in fruit drop. Stress induced ethylene signaling and reduction in endogenous auxin is associated strongly with fruit drop. Fruits with less seeds tend to drop early. Various researchers have suggested use of auxins at low concentrations to control fruit drop. Pathogenic fungi viz. *Botryodiplodia theobromae, Colletotrichum* *gloeosporioides* and *Alternaria citri* may cause 22% preharvest drop in the orchards having 10% dead twigs of the canopy (Naqvi , 1994). Insect pests like fruit fly (*Daucus dorsalis)* and fruits sucking moth *(Otheris sp)* may also enhance the drop. Use of synthetic auxins like 2,4-D and NAA @ 10-20 ppm has been successfully tested against physiological fruit drop. Cycocel application at 1000 ppm at the start of summer coinciding / with water stress has been found to increase the number of flowers retained (Anon, 2004).

2,4-dichlorophenoxyacetic acid (2,4-D), 2-(2,4-dichlorophenoxy) propanoic acid (2,4-DP), 3,5,6-trichloro-2-pyridyloxytacetic acid (Triclopir) (45 to 10 mg L-1) and gibberellic acid (GA3) (9.4 mg L-1)was reported to delay and reduce the undesired fruit abscission and senescence of 'Tarocco' blood oranges in Italy (Tumminelli *et al,* 2005)

4. Citrus decline

Citrus decline is another widely reported disorder in many parts of the citrus growing regions like USA, Mexico, Brazil, Argentina, South Africa, Iraq, Iran, Turkey, India, etc. It is attributed to occur due a variety of causes occurring usually in combination It is a symptomatic expression of many disorders in the plant and not a specific disease in India. Dhatt and Dhiman (2001) has reviewed the aspects of citrus decline elaborately.

A. Symptoms

Generally, the citrus plant after 5-6 year of excellent growth usually starts declining with gradual decrease in vigour and yield. Magnitude of decline increase with the age of plant and after 15 - 20 year affected plant become uneconomical. Declined tree does not die usually but remain unproductive. The symptom comprised of retarded growth of tree, appearance of chlorotic leaves, sparse foliage, die back of twigs and in general appears sickly. Ultimately his lead to death of the tree. The decline may be noted in as high as 40-60 % of the trees especially in mandarin.

B. Casual factors

The factors leading to the decline may be due to one or more of the following

- shallow soil (< 45 cm deep)
- hard pan in the subsoil surface
- moisture stress
- poor drainage of soil.
- higher pH
- higher EC value
- low organic matter in soil
- deficiency of N in soil and plant
- deficiency in endogenous hormonal levels
- Zn deficiency
- Stock - scion incompatibility (Eg 'Fairchild' mandarin on Macrophylla)
- Insect pests, diseases and nematodes

C. Management

- Integrated approach is required based on the factors associated
- Strategies should include use of virus free planting material, careful selection of rootstocks, timely management of nutritional needs, hormonal applications, use of organics, integrated pest and disease management, nematode control etc.

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Ma ageme t o(Eroductio Co strai ts i Eapaya

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A fruit of tropical America in origin, the delightful Papaya (*Carica papaya* L.), is now considered as one of the important fruit crops of tropical and subtropical regions in the world. Brazil, India, Nigeria, Indonesia, Mexico, Peru, Congo, Thailand, Venezuela, Philippines, Bangladesh, Hawaii in USA, Sri Lanka, Malaysia and Australia are the major production centers of papaya. Introduced from Philippines through Malaysia to India in the later part of 16th century, papaya cultivation has now widely spread in the tropical plains of our country. Besides as fresh fruits, papayas can be processed as jam, syrup, preserves etc. It is also the commercial source for protease enzyme 'papain' which is chiefly employed for chill proofing of beer, tenderization of meat and in preparation of several pharmaceutical products.

According to FAO estimates (2004), the world papaya production is 6.708 million tonnes from an area of 3,75,318 ha. The area under papaya in India is estimated at 80,000 ha and production at 7 lakh tonnes in 2004. Currently, India ranks fourth among in papaya producing countries with Brazil, Mexico and Nigeria ahead of her.

Varietal status

Among the countries that cultivate papayas, Hawaiian 'Solo's, and recently the Taiwan's 'Tainung' are popular. Introduced to Hawaii from Barbados during 1911, the 'Solo' has been continuously inbred and Kapoho Solo, Sunrise Solo, Sunset Solo, and Waimanalo are widely grown gynodioecious Hawaiian varieties. Research efforts in India, taken up by TNAU Coimbatore, IIHR, Bangalore and at IARI Regional station, Pusa, Bihar over the past three decades has resulted in several varieties (Table 1). Of these, the dioecious varieties CO.2, CO.5, Pusa Dwarf and the gynodioecious varieties CO.7 and Surya are noteworthy for their excellent features .

Besides the varieties from India, enthusiastic growers have introduced gynodioecious varieties such

Table 1. Improved papaya varieties from India

Varieties	Remarks
CO.1, CO.2, CO.4, CO. 5, CO.6 (TNAU)	Dioecious, yellow fleshed, dual purpose; CO.2 and CO.5 are high yielders and highly recommended for papain extraction; TSS-11-14%; yield potential of CO.2, CO.4, CO.5 and CO.6: 180-220 t/ha
CO.3 and CO.7 (TNAU)	Gynodioecious, red fleshed; ideal for table purpose; CO.7 is the latest variety released during 1997; CO.3-small fruited; TSS-12-14 % 120t /ha; CO.7-big fruited;13-16% TSS; 180 t /ha
Surya (IIHR)	Gynodioecious, medium sized, red fleshed , good keeping quality; TSS-14%; yield- 125 to 150t /ha.
Pusa Giant (IARI)	Vigourous; dioecious; yellow fleshed
Pusa Dwarf,Pusa Nanha (IARI)	Dwarf varieties; dioecious, suitable for HDP; Pusa Dwarf- high yielder; Pusa Nanha is a mutant; ideal for kitchen garden
Pusa Delicious and Pusa Majesty (IARI)	Gynodioecious varieties; TSS -10-13%
Pant Papayas	From GB Pant University, Pant Nagar; dioecious

as Red Indian, Tainung, Malaysian 'Eksotika' etc.

Wang Der Nan *et al.* (1999) reported development and release of a new variety Tainung 6; a selection in F 6 generation from a cross between Solo 1 and Sunrise solo. The variety is red fleshed, gynodioecious with low fruiting position (66.9 cm), and high yields (56.5 fruits or 25.1 kg per tree). Two transgenic papaya varieties (Rainbow and SunUp) resistant to PRSV have become available commercially in the USA since 1997 and in Canada since 2003.

Production problems

As papaya cultivation has proved to be remunerative than many other agricultural and horticultural crops, the area under cultivation expanded nearly three fold in the past one decade in India. The production of papaya, however, is beset with many problems in recent times forcing the growers to abandon its cultivation. Shortage of reliable seed material, use of inferior planting materials obtained from fraudulent seed suppliers, poor seed viability, lack of awareness on improved production technologies, papaya ring spot virus and poor disease management are the major factors hampering productivity of papaya. The problems encountered in papaya and management strategies to effectively overcome them are outlined here.

Variability in population

Based on the sex expression, papaya varieties can be either classified as dioecious or gynodioecious. The dioecious varieties produce male and female plants in 1:1 ratio when propagated from seeds. The gynodioecious varieties produce female and bisexual (hermaphrodite form) in 1:2 ratio. As papaya by nature is a cross pollinated crop, if pure bred seeds are not utilized for raising of seedlings wide variability leading to poor productivity is the result. Sex expression in papaya is also influenced by environmental conditions. While female forms are more stable, it is the gynodioecious forms which show floral abnormalities especially in adverse weather conditions. The extent of floral abnormalities varies also with varieties. It may be necessary to test the varieties under a location before expanding for commercial production in large areas.

Problems in seed propagation

Papaya is conventionally propagated by seeds. To ensure genetic purity, seeds should be obtained by sibmation or selfing depending on the sex form of the varieties. About, 500 g seeds will be required (200g / acre) for planting one hectare. The quantity of seeds required may be still less (~ 100g) if the seeds are small and if germination percentage is 90% and more.

The flesh of papaya fruit contains an inhibitor which can prevent germination. The sarcotesta can prevent germination, but drying freshly extracted seeds results in increased germination. Hence, the freshly extracted seeds are rubbed to remove the gelatinous sarcotesta and thoroughly washed in running water before being dried for storage. Pre-soaking the seeds in water for 24 hours is reported to promote germination in seven *Carica spp.* (Riley,1981). The optimum temperature for the germination of seeds is about 35ºC and temperatures below 23ºC and above 44ºC are detrimental to seed germination. Usually five to six seeds are recommended sown per nursery bag. It is wiser to buy the seeds after ascertaining the number of seeds per unit weight especially if the seeds are costly as in the case of some of the exotic varieties.

Seeds normally loose their viability quickly unless properly stored. Use of paper aluminum foil for seed storage up to six months and treatment with GA, at 200 ppm has been reported to result in highest germination (Vincent and Thandapani, 2000).

Most often, poor growth in the nursery can be traced to poor soil mixture, insufficient soil mixture, improper watering and incidence of seedling diseases and nematodes.

Problems in vegetative propagation

Conventional clonal propagation methods like grafting, layering and rooting of side shoots are possible (Ramkhelawan *et al.*,1999), but they have not become so far commercially viable.

Several studies have been taken up to propagate papaya through tissue culture and protocols have been published. TC plants offer scope for fixing genetically engineered traits, heterotic vigour, maintaining uniformity. In many instances, hardening of plantlets after successful *in vitro* culture is proving to be a hurdle in commercialization. In a recent publication, it has been revealed that tissue cultured plants came to flowering and fruiting two months earlier compared to transplanted seedlings (Fitch *et al.*, 2005).

Sex Identification

Different sex forms of papaya have been described by Storey (1953). If the nature of flower from which fruit is formed and source of the pollen is known, it is possible to predict the proportion of plant types in the progenies. Normally male trees flower earlier than female trees and can be easily identified as they have pendulous, hanging and branched stalk. In gynodioecious varieties, stamens can be noted adhering to petals surrounding the ovary. Efforts are in progress to evolve easy technique by which male / female plants could be distinguished at juvenile phase itself in various laboratories.

Varied attempts to predict the sex of the progeny by correlating seed colour, seedling growth rate, biochemical tests have been made with low degree of predictability. From a comparative analyses of leaf biochemical constituents of CO5 male and female plants and Sunrise Solo hermaphrodites, Dhara and Veerannah (1998) reported that leaf protein and IAA oxidase activity were higher in male plants followed by hermaphrodites and females. Phenol content was observed to be lower in females than males and hermaphrodites, but the reverse was observed for RNA and DNA contents. Female plants had higher cytokinin and lower gibberellic acid contents than males and hermaphrodites. According to Awad *et al.* (1999), in cv. Fairchild, pistillate plants could be detected early by the presence of higher dry matter content in leaf blades and petioles, silicon, total indoles, as well as leaf blade amino acid content and free proline. Staminate plants had higher ash content of leaf blades and petioles, peroxidase and free proline in petioles only. It is not possible to commercially adopt the results from these studies, as the extent of predictability is low.

Some of the recent developments involving studies related to molecular markers are promising. Sondur *et al*. (1996) constructed a genetic linkage map of papaya using randomly amplified polymorphic DNA (RAPD) markers and a F_2 population derived from a UH 356 x Sunrise cross and mapped the locus that determines sex to a 14 cM region flanked by RAPD markers.

Parasnis *et al*. (2000) of National Chemical Laboratory, Pune, have reported a PCR-based Seedling Sex Diagnostic Assay (SSDA) specially designed for early screening of papaya seedlings by developing a male-specific sequence characterized amplified region (SCAR) marker primer by cloning a male-specific RAPD (831 bp) fragment and designing longer primers. Hermaphrodite-specific markers have been reported by Lemos *et al*. (2002). Similarly, Urasaki *et al*. (2002) have also developed a molecular test to distinguish male and hermaphrodite plants from females.

The use of these molecular markers have been claimed to predict the sex with a high degree of accuracy. The commercialization of these techniques would be a boon to the papaya growers.

Soil and environment requirements

Well-drained fertile soils of uniform texture are highly suitable for papayas. Water stagnated conditions favour foot rot disease (*Phytophthora* sp). A loamy soil with a pH of 6.5 to 7.2 is ideal. Depending on the pH of the soil, 2- 4 tonnes of lime per ha can be applied.

Papaya is adapted to a wide range of rainfall conditions ranging from 35 cm to 250 cm annual precipitation; however, excessive moisture affects the crop as well as fruit quality adversely.

Optimum temperature for growth and development of papaya lies between 21 and 34 °C. Temperatures below 12-14°C will affect growth and fruitset. The productivity is better in warmer low lands with good humidity. A minimum relative humidity of 65 % is required for optimum growth. Use of micro sprinklers, if necessary, can increase the humidity. Papaya is easily susceptible to frost. Some of the wild species such as *C.candamarcensis*, *C.quercifolia* and *C.pentandra* have been reported to be frost resistant. It is better to avoid regions where frost is encountered.

Transplanting

It is necessary to transplant papaya at a proper stage of growth to establish a good field stand. Usually when the seedlings are grown to a height of 30-45 cm, they are transplanted. To ensure higher productivity, it is necessary to transplant 4-6 seedlings in a pit and allow them to grow till flowering. If seedlings are over grown, the basal leaves may be nipped off to avoid transpirational losses and the pit size should be proportionately larger to accommodate the roots.

Planting season

The best time to plant papaya in most parts of India is the beginning of the South-West monsoon in the light rainfall tracts and the end of the monsoon in the heavy rainfall tracts. June-September is the best season for planting in rest of the areas. In Tamil Nadu, papaya is planted normally during July. However, it can be planted round the year if irrigation facilities are available. For extraction of papain, planting during November is advisable under Tamil Nadu conditions. Hot summer months should be generally avoided for planting.

Planting density

Papayas are normally planted at 1.8 m x 1.8 m distance in pits of 45 to 60 cm3 size which are filled with decomposed FYM and top soil in 1:1 ratio. Double row system can be also used if needed providing a spacing of 1.8 m between rows and 3.0- 3.5m between paired rows to ease farm operations.

Trials taken up at Ranchi, Bihar, India, to study the effect of plant density indicated that at the closest spacing (1.5 x 1.5 m) plants were upright and tall and at wider spacing (3.0 x 2.5 m), stem girth was high. Though the average yield/plant was more (24 kg/plant) at the widest spacing and lowest at the closest spacing (7.8 kg/plant), overall average yield/ha was the highest (382.8 q/ha) at 2.0 x 2.0 m spacing and very low (284.0 q/ha) at 2.5 x 2.5 m spacing. Hence 2.0 x 2.0 m spacing was recommended for good yields and fruit quality (Singh *et al*., 1999)

From a study at Coimbatore, Ravichandranae *et al.* (2002) reported that a spacing of 1.8 m x 1.8m was optimum for yield and quality as compared to 2.1m x 2.1 m or 2.4m x 2.4m for CO.2 variety.

Thinning

The sex of the plants can be identified only after flowering. In dioecious varieties (in the seedling population) the male and female plants will be in 1:1 ratio. Keeping one male tree for every 20 females, the excess male trees should be removed. In the gynodioecious varieties in each pit, only one vigorously growing hermaphrodite tree should be retained.

Carpellody and Sterility

The bisexual forms of trees produce deformed and misshapen fruits very often. Stamen carpellody is the state in which the fruits get deformed because of improper development of stamens into carpel like structures embedding into the fleshy ovary and leading to ‘ cat faced’ fruits. Exposure to cool temperatures is attributed as one among the causes of carpellody.

Warm and dry weather conditions may force the normally productive bisexual trees into a condition of maleness resulting in ‘sterility’. Hermaphrodite plants grown under high tension (low moisture) soils produce higher extent of male flowers than those under low tension (high moisture) soils. While at temperatures below 17°C carpellody may result, at temperatures above 35°C sterility can occur (Singh, 1990). Micro irrigation generally reduces the extent of sterility.

Water management

Adequate moisture supply is essential at all stages of crop growth. While water stress induces maleness and poor fruit set, excess moisture can cause carpellody. Trials taken up at TNAU has revealed that conventional irrigation at 60-80 % available soil moisture depletion is found to be optimum for papaya. Conventionally, papaya plants are irrigated at 10-12 days interval in winter and weekly once in summer if there are no rains. Plants also perform well under drip irrigation when supplied with 20 to 25 l /day for bearing trees.

Nutrition management

Papaya is a heavy feeder and adequate manuring of young and mature papaya tree is essential to maintain the growth and vigour of the tree. The nutrients removed by the whole plant at harvest was 305, 103, 524, 327 and 183 Kg ha^{-1} of N, P, K, Ca and Mg respectively (Veeranah and Selvaraj, 1984). It is estimated that each tonne of fruits remove 2.8 Kg N, 0.8 Kg P and 2.3 Kg of potassium.

It is advisable to combine soil and tissue analyses to diagnose nutrient related problems. For nutrient analyses, Bhargava *et al*., (1989), recommend analysis of petioles of 6^{th} fully opened leaves from growing point 6 month onwards. The optimum leaf nutrient status as reported by them is : N-1.66 %, P- 0.50 %, K- 5.21 %,Ca-1.81 %, Mg- 0.67 %, S- 0.38 %

In various varietal trials, better response has been noted with up to 250g of N and 250 g of P and application of N and P at same rates produced better results. Application of K reflected in better fruit quality especially in TSS. Purohit (1977) and Sulladmath *et al.* (1984) recommended 250:250:250 g in NPK $plant^{-1}$ for the varieties Coorg Honey Dew and Solo. TNAU recommends application of 300g in each of NPK $plant^{-1}$ $year^{-1}$ at bimonthly intervals along with application of 20 g *Azospirillum* and 20 g *Phosphobacterium* at planting and again after six months.

Widest spacing of 2.4 x 2.4m and application of 400g of each of NPK at monthly intervals reported to enhance fruit yield (199.57 kg / plant), quality and generate highest additional net income in papaya cv. CO.2 (Ravitchandrane *et al.*, 2002).

Fertigation: As the vegetative growth and flowering is simultaneous in papaya, it is necessary to supply the required nutrients at optimal levels during the active growth period. Fertigation offers scope for enhancing yield and quality of papaya. Investigations taken up at TNAU during 2000-2001 revealed that application of 13.5 g urea and 10.5 g of muriate of potash / week through fertigation (irrigation to repalce100 % CPE) and soil application of super phosphate 278 g per plant in bimonthly intervals improved growth, yield and quality characteristics in papaya cv. 9-1 (D). Similar findings were also observed in CO.7 in subsequent years.

In studies with 'Solo' papayas, Allan *et al.* (2000) reported linear response of plants to applied N and quadratic response to applied K in the early stages and linear response at later stages to applied K.

Integrated nutrient management

Application of 75 and 100 % of recommended dose of 300 : 300: 300 g of NPK in sixs plits along with *Azospirillum* +VAM (50g/plant) + PSB + *Pseudomonas fluoroscens* (25g/plant) +*Trichoderma viride* (50g/plant) has proved to enhance growth and yield of papaya cv. CO.7 (Nandhini, 2004).

Micronutrients

Studies on micronutrient application indicated that foliar sprays of zinc sulphate 0.5% and boric acid 0.1% at 4th and 8th month after planting increase the yield and quality of fruits in CO.5 Papaya (Kavitha *et al*., 2001).

Boron deficiency may lead to latex exudation from fruit skin and tumor like eruptions on fruits (bumpiness). The deficiency can be controlled by spraying 0.1- 0.2 % boric acid.

Weed management

Weeds in papaya orchards can be effectively controlled by pre and post emergence weedicides. Paraquat can be employed at 0.25 to 0.35 % as pre emergent weedicide five weeks after planting. Pre emergent application of Fluchloralin or Alachlorin or Butachlorine (2.0g/ha), two months after transplanting can control all weeds for 4 months. For post emergent control, Paraquat @ 1000ml/500 litres/acre can be used. Glyphosate can be sprayed if the plants are above 1.2m tall at concentrations of 2.2 to 4.4 kg a.i. /ha. Weedicides sprays may cause injury to the young trunk and hence care should be taken especially on windy days. Mulching around the basins and drip irrigation helps to prevent weed infestation to a large extent.

Bioregulation

Several growth regulators have been tested in papaya with varied results. A summary of the recent research reports involving chemical growth regulation of papaya is tabulated below.

Purpose	Growth regulator & concentration	Reference
Early flowering	GA_3 25 ppm	Ghanta & Misra, 1998
Sex expression	GA_3 25 ppm 45 & 75 DAP;	Mitra & Ghanta, 2000
	GA_3 500 ppm 30 and 60 DAP	Subhadrabandhu *et al.*,1997
Increased papain yield	GA_3 50 ppm 45 & 75 DAP	Mitra & Ghanta, 2000
Increased Yield	25 mg paclobutrazol + 0.4% amino acids along with 300 g N	Auxcilia and Sathiamoorthy, 1999
Advancing maturity	200 ppm ethephon	Dinesh Kumar and Prasad, 1997

Pests and diseases

Some of the important pests and diseases of papaya along with control measures are tabulated below.

Pests / diseases	Control Measure
Scales, mealy bugs, aphids and thrips	Malathion 50EC 4ml/l (or) methyl demeton 25 EC @ 2 ml/l
Mites	0.1 % Kelthane
Collar rot/ Root wilt	Drenching with 1 % Bordeaux Mixture or 0.1 % CopperOxy chloride at Nursery stage; drench Metalaxyl (0.2%) in mainfield

Pests / diseases	Control Measure
Anthracanose	Copper oxychloride 0.2 per cent or mancozeb @ 2g/l .
Powdery mildew	Wettable sulphur @ 0.2%.
Ring Spot Virus	Field sanitation + control of Aphids
Nematodes	Application of carbofuran 3G @ 3g / poly bag at nursery stage and 15-20 g or Neem cake 250g + Carbofuran1g a.i + 4 g Pseudomonas fluorescens per plant in the main field

Among mites, two-spotted mite (*Tetranychus urticae*) and, in particular, broad mite (*Polyphagotarsonemus latus*) are the most serious pests. Major fungal pathogens of papaya include phytophthora rot and fruit rot (*Phytophthora-palmivora*), anthracnose (*Colletotrichum spp.*) and powdery mildew (*Sphaerotheca* spp). In australlia, incidence of black spot (*Asperisporium caricae*) and brown spot (*Corynespora cassiicola*) are also reported to occur.

Fruit flies are important pests to be checked. Several species like *Batocera cucurbitae, Batocera dorsalis, Ceratitis capitata, Anastrapha fraterculaus* are important in several regions of the world .

Papaya ring-spot virus (PRSV; Potyviridae) has become the limiting factor for commercial papaya production in many areas of the world including India leading to severe crop losses. Early symptoms include yellowing and vein clearing in young leaves and may be coupled with severe blistering and leaf distortion. Dark concentric rings and spots or "C"-shaped markings develop on the fruit, which may turn tan-brown as the fruit ripens. PRSV is transmitted by aphids (*Aphis gossypii and Myzus persicae*), mechanical transmission of sap and the movement of infected plants. In Australia, its spread is managed by a quarantine zone, which limits movement of papaya and cucurbits (eg. cucumber, pumpkin and watermelon) and by removing and destroying infected plants.

Ray *et al*. (1999) reported best performance of cv. Pusa Delicious with a marked reduction in viral infection by transplanting in October and with a heavy manurial dose consisting of 10 kg FYM, 2 kg castor cake,1 kg Cake-0-Meal, 200 g N, 200 g K_2O and 200 g P_2O_5 per plant per year applied in 2 splits, once in June and 3 months later. Spraying 0.5% Zn and 0.1% B in addition to the above manurial schedule did not bring any appreciable improvement in yield or noticeable reduction in viral infection.

PRSV resistant transgenic papayas

From a papaya transformation system where in young embryos from papaya seeds of the commercial Hawaiian solo cultivar 'Sunset' were transformed with the coat protein gene of a PRSV isolate from Hawaii and a promising transgenic papaya line (55-1) that showed resistance to PRSV from Hawaii was identified in 1991. The line 55-1 that is homozygous for the coat protein gene was later named as 'UH SunUp'. Another transgenic variety, which is a hybrid resulting from a cross of 'UH SunUp' and non transgenic 'Kapoho', (the dominant papaya cultivar grown in Hawaii) was also later evolved and named as 'UH Rainbow'. In the field trials the non-transgenic plants became infected 11 months after transplanting, while all but three of the transgenic plants have remained resistant to PRSV even 35 months after initiating the trial. These two varieties have been released for commercial cultivation in Hawaii during 1998 (Gonsavles, 1998).

Tennant *et al.* (2001) studied the resistance level of these transgenic plants after inoculaton with PRSV isolates from Hawaii, Brazil, Jamaica and Thailand. They reported that , young and older hemizygous Rainbow plants were resistant to the homologous PRSV HA (99.8% homology to CP transgene), while only older Rainbow plants were resistant to the other Hawaiian isolates (96.7% homology). However, all inoculated Rainbow plants were found, susceptible to PRSV isolates collected from Jamaica, Brazil and Thailand. Regardless of the plants developmental stage, 'Sun Up' was found to be resistant to all PRSV isolates, except the one from Thailand,. Resistance to the Thailand isolate, which shares 89.5% homology to the transgene, was observed only with SunUp plants inoculated at an older stage.

These studies indicate that, while it is possible to genetically engineer resistance, breakdown of resistance can happen depending on the developmental stage or with introduced isolates. Genetically modified PRSV-resistant papaya was developed in response to the devastating impacts of the disease, particularly in Hawaii and south-east Asia (Ferreira *et al*., 2002).

Tennant *et al*. (2005) have also selected a new PRSV virus resistant transgenic line 63-1, as potential alternative to the currently available genetically engineered 'Rainbow' and 'SunUp' papaya. Plants of this line showed considerable resistance (29 to 87%) when challenge inoculated with the isolates from Brazil, Thailand and Jamaica. Hence it has been identified as a potential line especially when strains of the virus, which can over come the resistance of Rainbow and SunUp, are accidentally introduced into Hawaii or are observed to occur in Hawaii.

Efforts are underway in TNAU, in developing transgenic papayas with PRSV resistance.

Biocontrol agents for nematodes

Inclusion of local isolates of *Paeciliomyces lilacinus* (10^6 spores /g) (IIHR - PL2) and *Trichoderma harzianum* (IIHR - TH1) (10^6 spores /g) at a dosage of 5 to 10 g / kg of soil in the nursery mixture was reported to be effective against *Meloidogyne incognita* (Rao and Naik, 2003) *Pseudomonas fluorescens @ 4g /* tree along with neem cake 250 g and Carbofuran 3G @1g a.i is proving to be beneficial in the research trials conducted at TNAU, Coimbatore.

Harvest

Papaya plants produce their first fruits in about 10 months from the time the plants are set in the field. The production of fruits is continuous during the life of the tree. Fruits can be harvested when they are still hard and green but turn slightly yellow. Papaya may live as long as 15 to 20 years and reach a height of more than 8 metres, but its economical life is only 2-3 years.

Yield

The average yield of different varieties of papaya released from TNAU, Coimbatore are as follows.

CO.1, CO.3	:	100-120 t/ha,
CO.2, CO. 4, CO.5 & CO.6	:	180-220 t/ha
CO.7	:	160-180 t/ha.

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Eroductio Co strai ts a d Ma ageme t i Sapota a d Guava

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SAPOTA (*Manilkara achras (Mill.) Fosberg)*

Sapota or sapodilla or chiku is a delicious tropical fruit crop which was introduced from tropical America. The Fruit Industry in India has made a remarkable progress during the last three and half decades. Mango, banana, citrus, guava and apple are the major fruit crops which account for about 75% of the total fruits produced in the country. In less-known fruits like sapota, ber and pomegranate area expansion and production during the recent year is spectacular. Among these, the area under sapota is fast increasing and this crop has attained the status of major fruit crop in Tamil Nadu.

The area under sapota in India during 2000-01 was 69,400 ha with a production of 6.74 lakh tonnes. In Tamil Nadu it was 3356 ha and 83900 t respectively. The important sapota growing states are Maharastra, Gujarat, Andra Pradesh, Karnataka, Tamil Nadu, Kerala, Uttar Pradesh, West Bengal, Punjab and Haryana. Recently our country has made a beginning in export to Middle East countries.

Production constraints

Though sapota is considered as a hardy crop which requires less attention, the national average productivity is very less i.e. 14.19t/ha which is due to the following field problems.

a. Narrow genetic base
b. Lack of technologies for rapid multiplication
c. Long pre bearing phase
d. Poor fruit set
e. Lack of technologies for canopy management
f. Problem in harvesting and storage
g. Pests and diseases

These problems have already received the attention of the scientists and the suitable management technologies evolved through field trials at different research centres are discussed below.

Crop improvement

Sapota in India, has a narrow genetic base and most of the varieties are the result of local selection for shape, size and quality of fruits. Some of the notable varieties which were evolved through selection were Guthi, Kalipatti, Kirthi Barthi, Thagarampadi, Dwarapudi, Cricket Ball, Bangalora, Oval, Banarasi, CO 2 (Banarasi), PKM 1 (Guthi) and PKM(S) 4 (PKM 1). Though PKM 1 is a ruling variety in Tamil Nadu, its fruit size is small and the keeping quality is also not good. Considering the fast increasing popularity and potential for commercializing this fruit both for domestic consumption and for export, there is a need to improve these locally popular cultivars incorporating the desirable fruit characters such as size, appearance, pulp quality, high sugar content, prolonged bearing period etc., through hybridization. A dessert sapota should have a pleasant sweet taste and good flavour with abundant mellow and melting type pulp. Hybridization is one of the means of effective improvement to

i. Widen the genetic base
ii. To enrich the germplasm collection which are high yielding and tolerant to different biotic and abiotic stresses
iii. To develop dwarf root stocks/varieties for HDP
iv. To develop rootstocks tolerant to pests and diseases
v. To induce and exploit useful genetic change through mutation.

Through systemic breeding work conducted at different research centers several hybrids were released which are listed below.

Sl. No.	Name of the variety	Parents	Special features
1.	CO 1 (TNAU, CBE)	Cricket Ball x Oval	Fruit is long oval, medium, flesh is granular and reddish brown.
2.	CO 3 (TNAU, CBE)	Cricket Ball x Vaviva lasa	Fruit is obovate to round, medium, juicy and very sweet (230B)
3.	PKM 2 (HC&RI, Periyakulam)	Guthi x Kirthi Barthi	Fruit is oblong to oval, big, very sweet (25 - 170B)
4.	PKM 3 (HC&RI, Periyakulam)	Guthi x Cricket Ball	Fruit is Oval, big, cluster bearer suitable for HDP
5.	DHS 1 (UAS, Dharward)	Kalipatti x Cricket Ball	Fruit is round to oblong, big, flesh is soft, granular, mellowing and very sweet (260B)
6.	DHS 2 (UAS, Dharward)	Kalipatti x Cricket Ball	Fruit is round and big, flesh is soft, granular, mellowing and light orange brown

Propagation

Though several propagation technologies have been developed for clonal multiplication of fruit crops, the propagation techniques for easy and rapid multiplication of sapota is yet to be refined. Unlike the other fruit crops, this is the only tropical fruit crop, which is commercially propagated using the seedlings of another species i.e. *Manilkhara hexandra* (Khirnee or Rayon or Pala) as rootstock for grafting. The results of the studies conducted in Gujarat, Kerala and Andra Pradesh revealed that Khirnee was the most vigorous and productive rootstock compared to sapota seedlings and *Bassia latifolia.* But the availability of Khirnee rootstock is a major problem in sapota propagation.

These rootstocks are not available in all areas as these require very specific soil and climatic condition for their growth. All the nursery men procure these rootstocks from far away places where these are available in plenty. This result is heavy expenditure on rootstock which in turn increases the cost of production of grafts. Among the fruit crops, the cost of sapota grafts is the highest (Rs.30/each) which is a major setback for area expansion.

Canopy management and crop regulation

The long pre-bearing phase, the large stature of the trees, poor fruit set, flower and fruit shedding are some of the production problems in sapota which can be managed through proper canopy management and crop regulation practices adopting the horticultural techniques viz., High Density Planting System, proper training and pruning of trees, use of bio-regulators, irrigation and nutrient management.

a. High density planting

Sapota trees are normally planted at a distance of 8 x 8 spacing accommodating 156 trees per hectare. Under this system due to less number of trees, the productivity is also low. In order to increase the productivity of sapota orchards, high density planting has to be followed for the efficient utilization of land and other natural resources. In a HDP trial in Kalipatti variety, Patel *et al.,* (1993) observed that 5 x 5 m spacing registered the highest yield. Identification of dwarfing rootstocks and management strategies may also help for HDP sapota. Patel *et al.,* (2001) reported that the six years of results on yield of sapota cv. Kalipatti had significant effect on yield with the highest yield of 13.61t/ha under 5 x 5 m and the lowest (5.05t/ha) under 10 x 10 m. The spacing trial conducted at Horticultural College and Research Institute, Periyakulam revealed that a spacing of 8 x 4 m (312 trees/ha) registered the highest estimated yield of 18.00t/ha in PKM 1 variety.

b. Training and pruning

Sapota is an evergreen tree and normally grows up to a height of 20 m. The different cultivars of sapota have four types of branching habit viz., erect, drooping, spreading, spreading but with fruits of inferior quality. Because of the unmanageable size of the trees and the different growing habits, the canopy management through training and pruning is very essential in sapota to increase the productivity. The studies conducted at HC&RI, Periyakulam indicated that the lowest tree height was obtained with medium pruning in sapota cv. PKM 1. The fruit length was also significantly influenced by pruning. Further, training the trees by retaining 3 or 4 tiers and removal of 50 percent of its side growth (moderate pruning) resulted in better yield and quality of fruits.

c. Use of bio-regulators

The problem of poor fruit setting and retention, shedding of flowers and fruits can be overcome through foliar spraying of bio-regulators. Ray *et al* (1994) reported that the highest fruit set and fruit retention was observed by spraying 100 ppm SADH before anthesis and one month thereafter in the cultivar Cricket Ball. To increase the number of flowers/ shoot spraying of COC@4000 ppm at fruit bud development stage was recommended (Delvadie *et al., 1994).* The results of the study on effect of pruning and paclobutrazol on production of sapota cv Kalipatti in high density plantation have indicated that 5 x 5 m spacing was beneficial upto 13 years. Further, the treatment of pruning and paclobutrazol had no significant effect on growth and yield of sapota cv. Kalipatti under high density plantation (Anon, 2002).

d. Irrigation management

Excess irrigation may cause flower and fruit shedding and increase the number of mis-shapened fruits. Young plants should be watered regularly during dry season and at an interval of 6-12 days during winter. The optimum level of irrigation lies around 0.5/1W/CPE ratio. Drip irrigation at the rate 20-30l/day/tree is recommended by Tamil Nadu Agricultural University. For the young trees which are in the pre bearing stage, 1/3 of the recommended dose of water may be given and slowly increased reaching the above level during full bearing stage.

e. . Nutrient management

In order to increase the productivity proper nutrient management should be followed. Being an evergreen tree liberal dose of fertilizers is required to maximize the productivity in sapota.

A nutrition survey of sapota orchards in Tamil Nadu has revealed that the low nutrient content in the soil was attributed for the poor yield. The application of 600g N and 400 g. K_2O per plant in PKM 1 sapota recorded higher yield of 29.50 kg/tree. In an another trial, the treatment with 5 kg vermicompost + 200:40:150g NPK per tree recorded the maximum tree height of 4.08 m and maximum fruits yield of 60.93 kg per tree.

In Maharashtra, the sapota trees are given yearly application of manures and fertilizers and an one year old tree gets 20 kg of farm yard manure and 400g castor cake and this dose is increased every year by 4 kg and 400g respectively.

In Gujarat, Maharashtra and Karnataka, for getting good response, the manures and fertilizers are applied in two splits. Under rainfed condition, it is advised that sapota trees should be fed at the rate of 1.5 kg N / tree/ year in the form of castor cake or urea. Fertigation studies with water soluble fertilizer indicated that fertilization with 80% of water soluble fertilizers at bi-monthly intervals yielded 5800kg/ha as compared to 4300 kg with 100% normal fertilizers applied through soil. Fertigation economized the use of fertilizers and water to the extend of 20-25 percentage (Shivashankar and Khan, 1994).

Harvesting and storage

Sapota fruits are highly perishable and have a very limited shelf life. Under ambient condition fruits after harvest keep well only for 5 to 7 days and are spoiled within a few days after ripening due to rapid degradative metabolism. Hence, post-harvest losses are enormous particularly during peak season. In order to have equitable distribution and to avoid crop loss and market glut, it is necessary to slow down the process of degradative metabolism by controlling the rate of transpiration, respiration and microbial infection through proper harvesting, handling and storage methods.

The studies on the effect of preharvest foliar application of calcium have indicated that application of 0.25 and 0.50% $CaCl/CaNO_3$ increased the storage life by 2-3 days and significantly reduced the post harvest fruit rotting (Lakshmana and Reddy, 1999).

The storage life of sapota fruits was extended when the fruits were harvested without pedicels. These fruits stored under refrigeration had higher weight retention compared with these stored under ambient condition (Brito and Narain, 2002).

The sapota fruits are ripened naturally in packages or in storage. Uneven ripening is a problem in sapota. The process can be hastened by using ethylene. The growth regulators viz., 2,4,-D @ 3 to 5 ppm or GA at 300 ppm kinetin at 150 ppm or AgNO3 at 40 ppm can be used to delay the ripening. Treatment with ethrel at 5000 ppm along with NaOH as dip ripened the fruits in two days (Shanmugavelu *et al.,* 1987). The investigations carried out at Horticultural College and Research Institute, Periyakulam revealed that among the different natural ripening media paddy straw was the best. The fruits dipped in 1000 ppm ethrel and the fruits in CFB lined with polythene sheets with 1000 ppm ethrel along with NaOH pellets was found to be the best (Nagaraja, 1998).

Sapota fruits could be stored for 9 days when packed in polythene bags (100G and 2% vents) under room temperature. The shelf life of fruits could be extended to 13 and 15 days by packing in polyethylene bags + CFB and stored in cool chamber (Wasker *et al.*, 1999). Likewise modified atmospheric storage with 5% (v/v) CO2 with exclusion of ethylene extends storage life. The ripening is best done at 20^0C. However, there is a need for standardization of these aspects both for domestic market and export.

In order to avoid the market glut during the peak season of supply, value addition through processing of fruits has to be done. But the processed products are not preferred due to heat liable delicate flavor, unagreable pulp color, intensive labour involved in peeling, presence of gummy material and development of acid taste and flavour loss in some products. However, attempt have been made with limited success to produce several processed products viz., sapota squash, sapota jam, jelly, sapota chutney, frozen sapota slices and pulp etc., Among the beverage viz., nectar, squashes and blended drinks prepared from ripe fruits, sapota - kokum drink registered the highest average organoleptic score, followed by nectar pickles prepared from unripe fruits and preserves from unripe and ripe fruits were quite acceptable.

An acceptable candy, sweets and milk shakes can be prepared from sapota pulp and powder showed wider acceptance. The osmodehydration could be an appropriate approach to bulk utilize this fruit but it needs standardization of techniques.

Flat Limb (Fasciation)

This disease is caused by *Botryodiplodia theobromae Pat.* and was first reported from Maharashtra and Gujarat. It is now reported to be prevalent in other sapota growing states also. However, later studies did not associate this fungus with this disease. In this case the affected branches become flat and twisted with rough marking on affected tissues. The leaves become thin, small and yellow and there is clustering of leaves and flowers at the top of affected twigs. Flowers remain infertile and fail to set fruits and even if fruits are set they remain small, hard and unripe. In severe case leaves fall prematuringly giving barren look to flattered branches and some times the thin shoot appears from the tip but finally dries out. Etiology of fungus remains to be worked out. It is recommended to prune and destroy the affected branches for controlling the disease. It is, however, necessary to understand the exact cause of the disease and methods of control.

Phanerogamic parasite

Phanerogamic parasite *Loranthus sp.* is most common in unattended sapota orchards. It reduces yield by reducing fruiting area and fruits are also of poor quality. The parasite is a glabrous shrub with green foliage but without true roots. Stem of the parasite is thick and erect and arise in cluster at the point of attack. This can effectively be controlled by cutting of the affected branches with tumors and their destruction.

GUAVA (*Psidium guajava L.)*

Guava is the fourth most important fruit of India both in area and production after mango, banana and citrus. On account of its high food value, a pleasant aroma, rich flavour and availability of moderate prices, it is popularly known a “apple of the tropics”. The area under guava during 2000-2001 was 1.48 lakh hectares with an annual production of 16.3 lakh tonnes. The important guava growing states are Uttar Pradesh, Madhya Pradesh, Bihar, Maharastra and Tamil Nadu. In Tamil Nadu it is cultivated is an area of 9719 ha with production of 44358 tonnes and the major growing areas are located in Dindigul and Madurai districts.

Production constraints

Guava is considered to be a poor man’s apple because of its high nutritive value and comparatively low price. Lack of technologies for rapid multiplication

1. Poor fruit set
2. Seasonal influence on quality of the fruits
3. Poor keeping quality of fruits.
4. Pests and diseases

Considering the above constraints in the production of quality guava fruits, several investigations were carried out throughout India and the results of these experiments to manage the constraints are discussed in this paper.

Plant propagation

Air layering and ground layering are the most important commercial methods in practice for propagation of guava. But the mortality rate of layers is high due to the improper selection of layering stick and also more number of layering sticks in the mother plant goes waste due to high mortality.

To overcome this, at IARI, New Delhi, a new technique known as **"stooling"** was standardized for faster multiplication of guava. In this method, the plants were headed back during December and then allowed to develop multiple underneath shoots. These shoots were ringed, applied with IBA (2500ppm) in Lanolin and earthed up as a mound to induce rooting. It can be successfully practiced twice a year. This technique has attained the status of commercial propagation method in India. At present, the inarching and bud-grafting are gaining importance and the technologies have to be standardized for cost effective production of grafts.

Rootstocks exert a great influence on vigour, cold resistant, fruitfulness, quality and disease resistance of the scion, but very little information is available for guava. In guava, several rootstocks are available like *P. cujavallis* produced the largest but non-uniform and rough skinned fruits, but produced high ascorbic acid content in fruits. *P. ponillum* had a dwarfing effect in addition to the increased sugar content of the fruits. Recently at IARI, Aneuploid No.82-a tetrasomic guava has been found to induce dwarfing in the commercial guava variety Allahabad Safeda. With the development of dwarfing rootstock, it is now possible to grow guava under high density concept.

Poor fruit set

The initial fruit set in nature is quite high and about 80-86 percent of the flowers set fruits. But due to severe fruit drop only 34 to 56% of the set fruits reach maturity. The fruit drop may be due to physiological, environmental and endogenous growth regulators. Spraying of GA_3 at 15 or 30 ppm in the month of January proved effective in increasing fruit retention and subsequently the yield.

Canopy management and crop regulation

The poor fruit set and the seasonal influence on the quality of fruits are the production problems which can be managed through proper canopy management and crop regulation practices adopting the horticultural techniques viz., high density planting system, proper training and pruning of trees, irrigation and nutrient management.

a. High density planting

Traditionally guava is planted at a spacing of 5m x 5m or 6m x 6m accommodating 278 to 400 plants /ha in square system of planting. Experimental results showed that higher plant densities decreased the fruit weight and size but the yield per unit area increased considerably. Guava cv. Allahabad Safeda, planted at 6m x 2m spacing and managed by hedge-row system produced the highest yield per hectare with better quality fruits. However, per tree yield was reduced as compared to 6m x 6m spacing. In another trial with the cultivar Sardar spacing did not significantly affect fruit set and flower /fruit drop. However, trees at 2m x 2m had lower yield per tree than those at 8m x 8m but produced a 10 fold higher yield per hectare. The studies conducted at Punjab Agricultural University, Ludhiana have indicated that the fruit yield was higher with medium spacing (6x5m), however, the quality was superior with wider spacing i.e. 6m x6m spacing (Bal and Dhaliwal, 2003).

At IARI, New Delhi high density planting was perfected by grafting Allahabad Safeda Guava on dwarfing Aneuploid No.82 rootstocks. A planting distance of 10 x10 feet accommodating 1111plants/ha is recommended.

b. Training and pruning

Training of guava trees has been found to improve the yield and fruit quality. The main objective of training guava plants is to provide a strong framework and scaffold branches suitable for bearing a remunerative crop.

The intensity of pruning had profound influence on flowering and fruiting in guava. Pruning of terminal 15 and 30 cm branches adversely affected flower production and reduced fruit yield /branch. However, severe pruning (30cm) had a beneficial effect on fruit weight and volume.

The guava trees produce fruits in two season viz., rainy season (Ambebahar) and Winter season under the agro-climatic condition of Uttar Pradesh. The rainy season crop is poor in quality whereas the fruits produced during winter season are better with less incidence of pest and disease. The investigations on effect of shoot pruning on the crop regulation in cultivar Lucknow - 49 carried out at NDUAT, Faizabad have revealed that the flowering, fruiting and yield in winter season was significantly influenced by different pruning treatments. The yield was the highest by 50 percent level of pruning in the month of May.

In another experiments with six years old guava trees of cv. Sardar at PAU, Ludhiana on the effect of time and pruning intensity on fruit quality has indicated that the fruit quality improved with severity of pruning i.e. pruning up to 30 cm levels. Severe pruning (upto to 16 pairs of leaves) in January was recommended to improve the quality of rainy season crop (Sahay and Kumar, 2004).

c. Irrigation management

The field trials on irrigation requirement of guava have indicated that the higher TSS content was determined at the lowest soil moisture content (1.23%) while the lowest amounts were obtained at the highest moisture content. The lowest amount of ascorbic acid content was obtained at 1.23% soil moisture (Ram and Rajputt, 2000).

d. Nutrient management

In Tamil Nadu a fertilizer dose of 1.0kg in each of N, P and K is recommended. In a recent study by Peraire and Mitra (1999), it was concluded that N, P and K at 75g, 100g and 75g per tree respectively in two, splits + 1.5kg of neem cake was best with the higher yield of 13.7kg/tree and 38.0q/ha with an average fruit weight of 96.39g. Among the different sources of potassium, improvement in yield and quality was marked with higher level of K particularly K_2SO_4 (2%).

Fruit quality and storage

Being highly perishable in nature, guava fruit should be marketed immediately after harvest. The shelf-life of guava fruit at room temperature is relatively short due to rapid development of fungal rots. However, the fruits may be stored for few days, to adjust the market demand. Wrapping the fruits in newspaper was found to enhance the shelf life of fruits by 3 days. Preharvest spray of calcium compounds reduced physiological loss in weight and titratable acidity, while they increased TSS, reducing sugars and pectin contents. The fruit firmness increased as the concentration of calcium increased in the fruits. Calcium nitrate delayed softening and enhanced the shelf-life of fruits. Controlled atmosphere storage using high CO_2 (10%) concentration delayed ripening but showed physiological injuries.

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Eroductio Co strai ts a d Ma ageme t i Amla

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Amla is a hardy, drought resistant fruit tree. A rare combination of character is its ability to withstand water stagnation also. It is also called Aonla, Aola, Amalaki, Dharty and Indian Gooseberry. The tree is found growing in the plains and sub-mountain on tracts all over the Indian subcontinent from 200 to 1500m altitude. Its natural habitat like other members of its family starts from Burma in the East and extends to Afghanistan in the West. Latitude-wise it starts from Deccan and extends up to the foot of the Himalayan ranges. The amla fruits are a rich source of Vitamin C. It is used to treat bronchitis, jaundice, diarrhoea and fever. The fruit extract is used in a number of ayurvedic and homeopathic preparations to prevent greying and falling of hairs.

I. Cultivars

Some of the popular cultivars include Banarasi, Chakaiya, Francis, BSR 1, NA 4 (Krishna) and NA 5 (Kanchan).

Constraints

There has been no standardization of cultivars and they are mostly known on the basis of size, colour or after the names of places. The performance of north Indian cultivars is not predictable under south Indian conditions and flowering is erratic. An in-depth study on performance of cultivars under various climatic conditions is yet to be standardized. In fertile soils, some of the cultivars revert to more of vegetative growth.

II. Planting Material

Amla is usually propagated by seeds, grafting and budding. Seed propagation which has been in practice has given a lot of variation in the progenies. Hence vegetative propagation was resorted to.

Constraints

Plants raised from seeds don't come true to type and produce small sized fruits, inferior in quality. Genuine planting material is not available to farmers, as most of the nurseries supplying the planting materials have not registered with the government. There are more chances of selling inferior planting material in the name of superior varieties. Standardization of potting mixture, containers for transport and post- propagation handling are other problems. Potting mixtures for long distance transport has not been standardized.

III. Training and Pruning

The main branches should be allowed to appear at a height of 0.75 m- 1m above the ground level.

Constraints

Branches of Amla trees often break off carrying heavy crop load due to the brittle nature of wood. Training and pruning have not been standardized. Water sprouts and rootstock growth poses a problem under favourable environmental conditions.

IV. Flowering, Pollination and Fruit Set

Constraints

NA 6 and NA7 have low sex ratio. The number of female and male flowers was lowest in the branches in the west direction. It is also difficult to identify the flowers which are very small. Flower setting is prolonged over a very long period. Poor flower set in some cases is observed due to staminate flowers. An increase in fruit set with hand pollination indicates the need of pollinating agents. In old orchards where NA 7 was introduced the cropping increased. This has brought to light the need of a pollinizer. BSR 1 does not need pollination, whereas some cultivars set fruits only when pollinizers are introduced. There has been no standardization of pollinizers for specific varieties till date. Therefore planting of mixed cultivars is recommended for better cross pollination resulting in better yields. Therefore a good breeding programme for Amla has to be developed. Blossoming sometimes occurs on branches, and due to heavy crop load, chances of breaking of branches are more.

V. Flower and Fruit Drop

Constraints

Flower and fruit drop is observed in three stages. The first drop is the highest as 70 per cent of flowers drop within three weeks of flowering due to degeneration of the egg apparatus and lack of pollination. The second drop occurs from June to September due to lack of pollination and fertilization. The third drop consists of fruits of various stages beginning from third week of August to October due to physiological factors.

VI. Pest And Diseases

Constraints

Bark eating caterpillar, shoot gall caterpillar and fruit sucking moths are important pests. Amla rust and blue mould are important diseases.

VII. Harvesting

Constraints

Once over harvest makes Amla unavailable in the market throughout the year. Manipulation of irrigation resulted in staggered harvest. This would make Amla available over a period of 10 months, which has brought drip irrigation as a component of cultivation. Heavy crop loads sometimes makes harvesting difficult.

VIII. Postharvest Handling and Storage

Constraints

No packaging technology has been standardized and cold storage facilities are not available. No diversified value added products are available.

IX. Marketing

Constraints

A proper market survey as far as demand and supply, and also area and production of Amla has not been done so far. No industrial tie up or buy back arrangement or contract farming is available; thereby farmers are not assured of a secure market. Above all middlemen are largely involved in the trade, with less benefit to growers.

Eroductio Co strai ts a d Ma ageme t i Ma dari a d Avocado

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1. Mandarin orange

The average productivity of citrus in India is 7.29 tonnes per ha which is far below the average productivity of 30-35 tonnes per hectare obtained internationally. In India, mandarin oranges (*Citrus reticulata* Blanco) are grown largely under tropical climatic conditions. For example, the famous Nagpur orange is grown in tropical vidarbha region of Maharastra in central India over 73 thousand hectares and Andhra Pradesh in South India. Over 56 thousand hectares enjoy a distinct tropical climate where there is no defined winter season with low temperature regime. The kinnow mandarins, however, is showing good promise and is commercially successful in North India states like Punjab, Haryana and Rajasthan falling under subtropical climate with distinct winter season. Similarly, the traditional mandarin growing areas of North eastern hills and the Coorg area of Karnataka state experience subtropical climate with high rainfall and low temperature during winter months.

Mandarin oranges (*Citrus reticulata* Blanco) are fruit crops of world wide importance and suited for subtropical climatic conditions**.** World production of mandarin in 1996 was about 15.6 million metric tons, which was about 15% of the world citrus total. The major producing countries (million t) were China (5.9), Japan (1.19, mostly Satsuma types), Spain (1.4), Brazil (0.76), Italy (0.45), Morocco (0.4) and the USA (0.5). However, by far the major exporters of fresh and processed mandarins were Japan, Spain and the USA. In India, the most important commercial citrus is the mandarin orange (Santras of Coorg, Assam, and Nagpur). Citrus fruits (mandarins, oranges, limes and lemons *etc.*) occupy 13% of the total area in fruits and contribute to 10.3% of the total fruit production. Among citrus, the mandarins occupy nearly 41% of the total area under citrus, with an annual production of 13.4 lakh tonnes. The areas where mandarin in commercially cultivated have distinct problem of varied nature. The major production constraints are

1. Uncertainity about the remunerative returns due to high density planting.
2. Unidentification of suitable rootstock scion combinations on a specific soil type.
3. Irregular flowering.
4. Inefficient irrigation and fertigation.
5. Absence of promising diagnostic techniques leading to an efficient diagnosis of nutritional problems.

Production constraints in mandarins are varied from the soil and climatic requirements to enhancement of fruit qualities and they can be classified as follows:

Soil and climatic conditions

Soil

Mandarins can grow well in a wide range of soils, but unsuitability of the soil could also lead to the failure of the crop. Soil properties like soil reaction, soil fertility, drainage, free lime and salt concentrations are some of the important factors that determine the success of mandarins. It thrives well in deep, loose, well aerated soils devoid of any hard pan layers of calcium carbonate in the root zones. A pH of 5.5 – 7.5 is ideal for mandarins. However, with suitable management the citrus could thrive well in highly acidic (pH 4.5) soils and in soils containing free lime (pH 8.5). Drainage of the soil is an important factor, while poor drainage is highly detrimental. Excess drainage leads to various nutritional imbalance problems. Presence of calcium pan within the feeding root zone adversely affects the permeability and aeration of the soil.

Mandarins are grown throughout the main citrus belt between 45°N and 35°S in the frost-free subtropical to semi-tropical climate. Being evergreen, citrus has no specific requirements for winter chilling, but cessation of growth activity during winter months helps in flower bud induction, resulting in spring flowering. The climatic factors like temperature, moisture (rainfall and atmospheric humidity), wind and light intensity are of principal importance for citrus, of which temperature plays a key role. Usually, a low temperature of –6.66 to -4.44°C is injurious to young trees and a temperature of -11.11 to -8.88°C is injurious to mature old trees. The Kumquats mandarins, *C. latipes*, *C.ichangensis* can tolerate low temperature. Hot winds and excessive heat during flowering and fruit set period are highly detrimental for good bearing and causes fruit drop and fruit sun-burn. Atmospheric humidity has bearing mainly on the physical characters of fruits whereas temperature imparts effects on fruit quality. Low humidity usually favours better colour development of fruits, while in more humid conditions the fruits are more juicy with thin rinds.

Availability of quality planting materials and importance of certified nurseries

Selection of rootstocks should be made in a region specific manner based on their ability to tolerate or resist the different viral and soil borne fungal diseases that occur on Citrus. Bold seeds from such rootstocks are to be selected and raised with sufficient quantity of organic manure in a well drained fertile soil free from soil borne pathogens and nematodes. Seeds should also be treated with fungicides to avoid seed borne infection. The off type seedlings of sexual or hybrid origin are to be rouged out to maintain true to type nucellar seedlings which are uniform in plant stand. The optimum temperature for germination is highly variable with the rootstock and it varies from 25°C for *P. trifoliata* to 32.5°C, for Rangpur lime x Troyer citrange.

Selection of bud wood

The bud donor trees are selected based on their true to type nature, high vigour and yield. The buds from the donor trees are budded on indicator plants in insect-proof scion houses to screen for the occurrence of the viral diseases. The standard indicator plants employed for the indexing are Kagzi lime, West Indian lime for tristeza virus, Etrog citron and Rangpur lime for exocortis virus; sweet orange for psorosis virus and sweet lime and Orlando tangelo for xyloporosis virus. By this process, disease free donors are selected.

Bud wood certification programme

Bud wood certification and registration programme has been initiated at four centres located at Poona, Ludhiana, Tirupati and Kahikuchi (Assam) for different varieties of citrus. At each centres, the certified bud woods can be produced following procedures as detailed above. Australia is relatively free from the citrus virus problems because of the effective adoption of the bud wood certification programme.

Importance of propagation methods and rootstocks

The propagation of mandarins is mainly as seedlings or as T-budding. Since most of the citrus species and varieties are polyembryonic, the propagation of nucellar seedlings alone carry the true characters of the mother plants, thus enabling to retain the clonal characters as in vegetative propogation. The phenomenon of polyembryony also helps in raising uniform seedlings.

However, for grafting or budding, proper selection of rootstock is of profound importance to impart marked effects on the vigour, precocity, productivity, physico-chemical characteristics of fruits, longevity of trees, disease resistance, adaptability to soil – climatic conditions, *etc.* Root stock studies at Horticultural Research Station, Thadiyankudisai revealed that the Mandarins on Rangpur lime rootstock recorded better performance among the six rootstocks (*viz.*, Rough lemon, Cleopatra mandarin, Carriza citrange, Troyer citrange, trifoliate orange and Rangpur lime). The mandarin orange on Rangpur lime recorded the maximum plant height of 3.78m and produced the highest yield of 21.2kg/tree. This was followed by the trees on Rough lemon rootstock with a tree height of 3.58m, with a tree yield of 18.6 kg.

Jatttikatti (*C. jambhiri*) has been found to be the best rootstock for Kinnow mandarins of Punjab. For Nagpur mandarins, Florida rough lemon was found to be superior to karnakatta, while trifoliate orange was incompatible. The rootstock Kodakithuli (*C. reshni* Lush) has been found to perform well in Pannaikadu region.

Planting and spacing

In the north-eastern region of India, seedling-origin Khasi mandarin orange orchards are usually very closely spaced and in the old orchards, trees are found to grow even 2-3 metres apart in an irregular way. Mandarin orange being more or less upright in growth habit, particularly, when raised from seeds can be planted at a distance of 5-6 metres. In Haryana conditions, a spacing of 5x4.5m was found to be optimum for Kinnow mandarin budded on jatti khatti (*C. jambhiri*) rootstock, while a closer spacing of 3x3m was found to be unsuitable for Nagpur mandarin budded on rough lemons. Coorg mandarins are planted at a spacing of 4.5m.

High density planting in mandarin

Mandarins are characterized by precocity and heavy bearing which has initiated the idea of close spacing in the initial years of bearing to realize better returns. A high density spacing of 6.0x3.0m under hedge row system (ie) 6.0m between hedges and 3.0m within row produced more yield per ha with regards to Nagpur mandarins and the fruit quality was also not much reduced as compared to the regular spacing of 6.0x3.0m (Ingle and Athawale, 2001).

High density planting is also practiced to maximize the yield per unit area. High density planting of Satsuma mandarin accommodating 1666 to 3333 plants/ha considerably increased fruit production. Practising ultra high density planting with more than 5000 plants / ha of Satsuma mandarins in Japan, a significant increase of fruit production have been recorded. However, in high density plantation, the life span of a cultivar may be reduced.

Though the planting is usually done during the monsoon season, it is better not to plant at the time of heavy rains to avoid any waterlogging near the planting pits. Weather should not be too wet or too dry at the time of planting.

Nutritional management for manadarin orange

Manuring and fertilization

Mandarin is a nutrient loving plant and about 15 elements have been known to play an important role for proper growth and development of the fruit. In addition to the major nutrients like N, P, K, Ca, Mg and S, citrus requires micro-nutrients like Zn, Cu, Mn, Fe, B, Mo, *etc*. Inadequate plant nutrition causes serious disorder in citrus and may eventually lead to decline of the orchards.

Nutrient uptake studies for profitable production of mandarins are 182kg N, 54kg P_2O_5, 205 kg K_2O. In bearing stage of Khasi mandarin, a dose of 300g N, 250g P_2O_5 and 300g K_2O per tree applied annually was found economical for increased production. Application of 600g N, 200g P_2O_5, and 400g K_2O annually per plant is recommended for Coorg mandarin. In Turkey, the highest fruit yield of Satsuma mandarin was obtained with 475g N, 320g P_2O_5 and 355g K_2O annually per plant. Leaf nutrient status can be used as an index for fertilizer application.

The following doses of manures and fertilizers are recommended for mandarin under Pulney hills in Coffee based cropping systems.

Manures and Fertilizers	I yr	II yr	III yr	IV yr	V yr	VI yr
FYM (kg)	10	15	20	25	25	30
N (kg)	0.100	0.200	0.300	0.400	0.500	0.600
P (kg)	0.040	0.080	0.120	0.160	0.160	0.200
K (kg)	0.050	0.100	0.200	0.300	0.300	0.400

In Shervoroyan Hills (Trees > 6 yrs) 700:375:600g NPK with VAM @ 1kg per tree is applied every year. Trials conducted at Horticultural Research Station, Yercaud revealed that application of 'P' as enriched FYM (0.5 kg P_2O_5/tree mixed with 20kg FYM) along with 700g 'N' and 600g K_2O/tree recorded the highest yield and improved the fruit quality of mandarin.

In a trial at Horticultural Research Station, Yercaud, application of 375 g of P_2O_5 as mussoriphos and 500g VAM recorded the highest yield of 35.35kg with 386 fruits pr tree. Nutritional experiments conducted at AAU, Tinsukia revealed that the application of 600:300:600g N, P_2O_5 and K_2O with 7.5 kg neem cake / plant recorded the maximum growth and yield (180kg/ plant) in khasi mandarin under Tinsukia conditions.

In light textured (sandy clay loam) acidic (pH 4.5) soils of Assam, application of Neem cake (7.5kg/plant) along with full dose of 600:300:600g NPK (T4 and T5) was found to maintain soil availability of NPK and produced the maximum yield and pest quality khasi mandarin (Huchche *et al.*, 2001).

Slow release for N is very much essential for well drained soil and hill zone mandarins, the leaching losses of N are very high. Slow release fertilizers like gypsum and neem cake coated urea was found suitable for Nagpur mandarins with enhanced yield and leaf nutrient concentration (Borah *et al.*, 2001).

To combat this problem, foliar spray after the new leaves have expanded to at least 2/3rd of their normal

Micronutrients deficiencies

Magnesium	In acid soils / leached soils - yellow blotches start along the midrib.
Calcium	Found in acidic soils and in areas with high rainfall where leaching loss is great. Twig dieback and profuse flowering. Premature shedding of flowers and weakened stems.
Zinc	Severe mottling of leaves. Little leaf and sparse foliage. Inter-vein chlorosis and resetting of terminal leaves occurs.
Copper	The foliage or copper deficient trees may be dense and dark green in colour, later twigs die back, leaving very small, yellow green leaves which fall of easily. Gum pockets between the bark and the wood at or near leaf nodes may be present.
Boron	The general symptoms of B deficiency are a tendency to leaf thickening, wilt, buckling of leaves, yellow veins, corky veins, thick leaves, puckering along the midrib, small water - soaked spots becoming translucent with maturity on the leaves.
Iron	Characteristic chlorosis (Interveinal chlorosis). Young leaves are affected first.
Manganese	Immature growth is mottled with light green or yellowish - green areas between the major veins. Leaf size remains unreduced. The leaf veins and small adjacent areas of the veins remain green. Shady side of the leaves show more pronounced symptom. It is common in acidic coastal soils and alkaline soils.
Molybdenum	Light green spots appear in 3 to 4 months old fully enlarged leaves. The spots are fairly small in mandarins.

size can be under taken using the following chemicals

Zinc sulphate	2.5kg
Copper sulphate	1.5kg
Manganese sulphate	1.0kg
Magnesium sulphate	1.0kg
Ferrous sulphate	1.0kg
Borax or boric acid	0.5kg
Urea	5.0kg
Lime	4.5kg
Water	450litres

Among the different foliar application of micronutrients on mandarin, at Horticultural Research Station, Thadiyankudisai, Magnesium and Manganese at 0.5 % conc. with 1% Urea spray recorded the maximum plant height (449.20 cm). Foliar spray with zinc and manganese at a similar concentration along with urea produced maximum number of fruits (276.6) and fruit weight (140.29). With respect to the quality, both the treatments produced fruits with the same brix (9.0°).

Application of $ZnSO_4$, $MnSo_4$ and $MgSo_4$ at 0.5 per cent and $CuSO_4$ at 0.25 per cent on Coorg mandarin revealed that Zn, Mg alone and combined spray of Zn+Cu+Mg reduced chlorosis as well as the deficiency symptoms of the elements and significantly increased the growth parameters. Foliar application of Fe-EDDHA at 250 to 500ppm 0.5% $FeSO_4$ increased yield and improved fruit quality of Balady mandarin in Egypt.

Flowering and fruit regulation

Flowering

Major blooms of all citrus species occur during the early spring (February - March) when the atmospheric temperature starts rising after the cold winter and soil moisture condition also improves. However in South India, with no well defined winter the flowering season is very long and well defined with two crops or more. The flowering can be regulated by inducing soil – water stress or through fruit thinning by chemicals and adjustment of fruit harvesting. In the absence of sufficient low temperatures in central India, soil water stress is usually practiced for induction of flowering in Nagpur mandarins. The success of flower induction depends upon the right quantum of water stress as a function of the soil physico-chemical properties. Regulation of flowering by use of growth promoters revealed that in Satsuma mandarins the flower bud formation was inhibited by foliar GA_3 level in October and that high IAA and ABA contents in December also promoted the percentage of leafless inflorescences and the number of flower buds per node. Mepiquat chloride (1000ppm, one spray) and cycocel (2000ppm, 2 sprays) were found highly effective in improving the flowering intensity of irregular flowering orchards of Nagpur mandarin. In Baladay mandarins the application of the paclobutrazol (2000ppm) at the beginning of flower bud induction reduced the intensity of alternate bearing and regulated cropping in the subsequent year. Application of 2,5,6-Trichloro-2-Pyridoxylacetic acid) at 10mg/lit after june drop gave best results in terms of fruit size, yield and fruit quality in clementine mandarins. GA_3 reduced the alternate bearing tendency of Kinnow mandarin trees particularly when applied at 20ppm.

Fruit set

Unfavourable conditions like late frosts, drought or excessive rains results in poor fruit set and high fruit drop resulting in poor yields.Considerable loss in the soil moisture can be reduced by mulching the soil to reduce the fruit drop. Nei lei *et al.* (2000) found that girdling or ringing increased the fruit set percentage in Shatianyou pummelo by 164.3% and the yield was increased by 21.8%. Application of gibberelin sprays have been found to be beneficial in Clementine mandarin. However there were some undesirable effects on the fruit quality with gibberelin treatment.

Fruit drop

High rate of fruit drop is a serious problem of citrus in India. Application of GA_3 (200ppm), at one month after anthesis increased the fruit set by 65% and reduced abscission of fruits, however the fruit size was relatively smaller in the treated plants than the untreated plants.GA_3 and 2, 4 – D proved effective in reducing the fruit drop in Darjeeling mandarin. Spraying with 50ppm of 2,4-dichlorophenoxypropionic acid in May increased the fruit weight of the Satsuma mandarins by up to 15% over the control.

Physiological disorders

Granulation

Juice sacs of citrus fruits become comparatively hard, assume a greyish colour and become somewhat enlarged, with an increase in pectin, lignin and other polysaccharides resulting in considerable decrease in juice, TSS, acid and water content, Several factors, such as high RH and temperature during spring, time of picking, tree vigour, *etc.,* influence granulation in citrus. Some success has been reported in reducing the incidence of granulation by lime spray at 35 to 40lb per 100 gallon water, less frequent irrigation, delay in the onset of granulation by spraying of 2,4-D at 16ppm and treatment with Zn+Cu+K (0.25 per cent each) three times between August and October.

2. Avocado

The avocado (*Persea americana* Mill) is originally a fruit of Mexico in Central America. It belongs to the family Lauraceae. It is commonly called as butter fruit. It is not exactly known when it was first introduced into India but it seems it may have been introduced in the south and west coasts of India about 50 to 75 years ago from Ceylon. In South India, it is at present grown only experimentally in a few orchards at Bangalore, Shevroys, Nandi Hills, Lower Palnis, and at the Kallar and Burliar Fruit Stations in the lower foot hills of the Nilgiris. In western India, avocado was for the first time imported from Ceylon in the year 1941 and planted at the Ganeshkhind Fruit Experiment Station, Poona.

Varieties

Three races of avocado have been recognized, the Mexican, the Guatemalan and the West Indian. These three races are botanically classified into two distinct species of *Persea drymifolia* and *Persea americana.* The Mexican race is included in the group *Persea Americana.*

West Indian varieties

Fuchsia, Peterson, Pollock, Simmonds, Trapp

Guatemalan varieties

Taylor, Eagle rock, Itzamma Linda, Schmidt, Wagner, Queen, Challenge, etc.

Mexican varieties

Gottfied, Puebla , San Sebastian , Duke

Inter-racial hybrids

1. Guatemalan x West Indian

   (a) Collinson (b) *Winslowson*:

   Fuerte, The purple, The Green, TKD-1.

Propagation using grafting techniques and overcoming

Avocado is commonly propagated by seed. Treating the seeds with GA at 100 or 1000ppm or in deionised water for 24 hours resulted in earlier germination.

Seed germination could be accelerated by slicing off 3-4 cm of the seed at the base and tip. Removing the seed coat also hastens the germination. Stratification of the seed accelerated early germination. Soaking the seeds in water at 30°C or 40°C for 8 hours improved the germination by 97 percent.

Planting system

The distance at which the trees should be planted in the orchard will have to be determined according to the vegetative vigour developed by the tree of a particular variety in a given set of environment, type of soil and by the shape of grove. The practice now is to plant the trees about 7 m apart, and there is even a tendency to plant more closely. Under Poona, 8 to 9 m spacing is given for purple and green varieties. Before planting, pits of 60 x 60 x 60 cm have to be dug and filled with leaf mould, top soil and well rotten farmyard manure.

Nutrition management

In avocado, flushes of shoot and root growth appear to be synchronizing and alternate on 30 to 60 day cycles. Shoot growth virtually ceases during late autumn and winter, but root growth, though it slows down during winter, continues throughout the year. Therefore, avocado requires heavy manuring. Young avocado plants should be fertilized with fertilizer mixture containing N:P:K =1:1:1, while the older trees should be given at a proportion of 2:1:2 nitrogen fertilizer alone reduces the yield and considerably increases the percentage of fruit with physiological disorder as compared to combined application of N,K and Mg. Autumn fertilization with N and P has been found to increase the mean yield of avocado.

Floral behaviour

Avocado trees have a mechanism of "Protogynous diurnally synchronized dichogamy". It is a cross pollinated crop. In avocado, dichogamy has been reported in that pistil mature before the stamens begin to discharge pollen. Alternate development of sex organs is decidedly synchronous for the tree as a whole and cross pollination is therefore essential for fruit setting.

Under bright clear weather, avocado flowers exhibit a marked tendency to open and close in unison and to open and close for two distinct periods at different times during 24 hours. The pistil is almost receptive, only during the first period of opening; during the second period, the pollen is shed. In most varieties, there is little overlapping of the two opening periods, only a few of the flowers being open for the first time (Pistil receptive). When flowers open for the second time, pollens are shed. All varieties which opened for the first time in morning are grown up together in class A and all those having their first opening in the afternoon are grouped into class B. In both the groups, a second opening of the flower occurs, at which time the pistil is no longer receptive but the pollen is shed. The intervening period of 18 to 36 hours separates the time of maturity of the sex organs in each flower.

Weather conditions exercise a marked influence on both the time and periodicity of the flower opening; this periodicity is most marked in bright clear warm weather, it is least produced in cool cloudy weather.

The pollen must reach the stigma at the proper time in the flower and pollination of the same type, close or cross, must take place for first set. There are three methods to enhance cross pollination, viz., planting trees of two varieties in the same hole, grafting of branches with pollinating varieties and alternating trees of different varieties.

At Kallar and Burliar foothills of Nilgiris, it has been observed that November – December flowerings are occasional and not very dependable for successful fruit setting, but the March and April flowering set a successful crop. In California, it was reported that embryo abortion is the major cause for the non-setting of fruit and is associated with low mean temperatures during flowering and fruiting periods. For the variety, Fuerte, the critical temperature is 13.3°C and for increased fruit set, the temperature should be above this limit.

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Ber – *Zizyphus mauritiana*

Ber is an ancient fruit crop of India and is relished for its sweet and sour fruits. The fruits are nutritious containing high amount of vitamins like C, A and B complex. The genus *Zizyphus* belongs to the family Rhamnaceae, consists of 40 species of tropical and subtropical regions of northern hemisphere. *Zizyphus jujube* (Chinese jujube) and *Zizyphus mauritiana* (Indian ber) are the two important species grown widely in temperate, tropical and subtropical regions of the world respectively. *Zizyphus ruggosa*, *Zizyphus nummalaria* are other important species of *Zizyphus.*

Varieties

There are more than 125 ber cultivars grown in India which are developed mostly by selection in different regions. They have synonyms also, eg: the cultivar Umran is also called as Katha, Ajmeri, Chameli etc. The cultivar chhuhara is other wise called as Rasmi. Commercial cultivars of ber are grouped as early, mid season and late in different regions based on their fruit maturity. Fruit maturity time in south India however varies.

Early varieties **-** Gola, Safeda, Seb, Badami, Nazuk, Banarasi, Gola - (**February).** Mid season varieties- Kaithali, Banarasi karka, thornless, Mundia,Tikadi Sanaur-5, etc. **(February- March)** Late varieties **-** Umran, Illaichi, Katha, Chameli **(March - April)**

Climate and soil

Wild ber is seen in almost all parts of India except in regions of low temperature. Ber prefers hot and dry climate for quality fruits and production. Ber can be grown up to an altitude of 1000m from MSL. Tree growth, flowering, fruit development and maturity seem to be more or less correlated with temperature and thus vary.

For good growth and bumper crops in ber, deep sandy loam soil with neutral to alkaline pH is desirable up to 9.2 though ber crop is grown in saline soils. Existence of varietal difference on tolerance of ber plants to salinity is observed.

Propagation

Existence of old orchards of ber in India is raised by seedling only. Vegetative propagation by patch or shield budding of commercial varieties is practiced to maintain ber plantations economically.

Planting

A plant spacing of 6 m x 6 m is followed for ber plantation of budded plants in south India and 7 -8 m spacing is followed in North India. Monsoon period i.e June -July (in south India) and August **-** September in (North India) is preferable period of planting time for ber.

Irrigation

The budded plants are to be irrigated immediately after planting and within an interval of 3 **-** 4 days for two months. Thereafter in the interval of irrigation can be extended as 7 to 10 days till to the establishment of new plants though ber is considered as an arid crop. For adult grown up trees, irrigation during fruit development in November to February is essential than any other period of growth for production of quality fruits.

In desertic conditions where soils are very coarse textured and irrigation is scares, a double walled earthern pot called as Jaltripti is used to irrigate the plants with less moisture evaporation loss which also reduces the mortality.

Training

Unless ber trees are trained, the trees become bushy, unproductive and hinder all intercultural operations. To establish a frame work of the ber tree train the trees with a single stem upto a height of 75 – 90 cm in the first year. Later, three to five main branches widely spread at all directions may be encouraged. The same process should be repeated to develop tertiary branches as secondary shoots. Final balancing and correction of frame work should be done in the third year.

Pruning

Pruning keeps the trees productive and improves fruit size, weight and quality. Regular annual pruning of all secondaries of one year old growth is practiced in ber during April may in different regions of the country. Pruning is generally practiced after the harvest of fruits in hot and dry season and trees become dormant. The pruning seasons are,

North India - middle of May

South India - during April and

Deccan Plateau - end of April.

Manuring

A well grown tree of 10 years old ber tree 30-50 kg of FYM, 250 g of N (in two split dose ie. August-September, November-December). 250 g of P_2O_5 (in single dose) and 50 g of K_2O per tree per year under adequate moisture conditions. In western Rajasthan, application of 10 kg of FYM for one year old plantation and then increasing the dose by 10 kg for each year upto 5th year is recommended (Pareek, 1983). Foliar application of 2% urea at pea nut size is found to increase the quality of fruits interms of improved TSS, and decreased acidity content.

Age of tree (year)	FYM kg/tree	N	P	K	Doses
1.	10	250	125	125	12-every month
2.	20	250	125	125	3-Jan, June and September
3.	30	500	125	125	3-Jan, June and September
4.	40	500	125	250	2 at pruning and flowering
5.	50	600	250	250	2 at pruning and flowering

Flowering

Time and duration of flowering varies with cultivar and location. Flowering of ber starts from July and extend upto November in different regions of the country. In South India flowering starts from July and continues to September with major fruit set in August itself. The flowers that appear in the early season are male and towards end of the season, are hermaphrodite. Providing set honey bee colonies in ber orchards help in to improving fruit set in many commercial cultivars as some are self unfruitful and self incompatible. Spraying of growth regulator like GA_3, 2, 4, 5 - T and 2, 4 - D is found to improve the fruit set from 9.6 % to 28.80%.

Harvest

Ber fruits are harvested in 4 -5 picking, as fruits do not ripe at a time. Picking is done manually either by hand picking or beating with bamboo sticks. Grade the ber fruits before packing and marketing to get premium price.

Major production problems of ber and their management

1. Fruit drop

Fruit drop in ber tree may be due to any one or combinations of following reasons as disintegration of ovules, Shrivelling of fruits and High incidence of powdery mildew. Fruit drop depends on cultivar, maturity period of cultivar (early, mid or late) and extent of fruit set, and bearing of tree.

Fruit drop has been found to be reduced by

i. Application of either 2,4-D (10-20 ppm) or 2,4-5-T (5-10 ppm) or GA_3 (25 ppm) in cultivars like kaithali, umran.

ii. Timely irrigation of ber trees after fruit set.

iii. Application of adequate quantity of organic manures fertilizers during fruit development – 50 kg FYM, 250 g N + 50 g P_2O5 + 50 g K_2O per tree after pruning and fruit set.

iv. Application of NAA @ 10ppm at fruit bloom is found to improve the fruit size

v. Foliar application of Borax and zinc sulphate is found to improve quality of fruit.

vi. Application of ethrel also observed to increase the weight and TSS content and reduced the specific gravity. Improvement of fruit colour from green to pink, fruit weight and reduced acidity can be achieved by bud treatment just before sprouting with 0.5% EMS.

2. Diseases of Ber

S.No.	Diseases	Symptoms	Control measures
1.	Powdery mildew-*Odium* spp	Leaves shrinkage and defoliationFruits dark brown,corky, canker,misshapen, under developed	a. Karathane-0.2% or bavistin-0.05% or sulphur dust @ 250 gs/ tree. b. Resistant cultivar-chhuhara,gola,thornless
2.	Sooty mould-*Isariopsis indica*	Black spots on lower surface of leaf, drying in Sept-Oct	Dithane Z-78 0.3% or COC-0.6%
3.	*Alternaria* leaf spot	Necrotic spot on leaves and drying in Jan-Feb	COC-0.3% or Dithane Z-78 0.3%
4.	Rust-*Pakospora zizyhivulgaris*	Irregular(brown to black) rust on lower surface of leaves, pre mature defoliation	a. Bavistin-0.1% b. Resistant cultivar-gola and banarasi
5.	Fruit rot-*Phomopsis* spp, *Colletrotrichum* spp, *Alternaria* spp	Brown spot on distal end of fruit	Dithane Z-78 0.3% or Blitox 0.2%

3. Pest of Ber

S.No.	Diseases	Symptoms	Control measures
1.	Fruit fly-*Crpomyia vesuviana*	Gullies inside the fruits ,deformed brown coloured, rotten fruits	a. Removal and destruction of infested plant parts,b. Ploughing the soil (May - June and August)c. Rogar 0.05% in Feb- March Resistant cultivars -Illachi, Umaran
2.	Bark eating caterpillar - *Indarbela quadrino tata*	Galleris of frassy web near the fork of tree branches	a. Painting the holes with 0.1% monocrotophos b. Mixture of 100g of soap + one litre of Kerosene inside the hole c. Resistant cultivars - Desi Alwar
3.	Hairy caterpillar - *Euproctis fraterna*	Feed on leaves, fruits and tender shoots	Dusting of 10% Lindane (or)0.1% carbaryl (or) endosulfan
4.	Lac insect	Suck the sap of branches Scale like appearance of twigs& branchesSeason of infestation - April - May and September	a. Spraying of Rogor@0.25% or b. Dimecron Destroy infected twigs / branch
5.	Fruit borer - *Meridarches scyrodus*	Feed on fruit - pulp and leads fruit rot Secondary attack by fruit rot fungus also	Monocrotophos - 0.2% twice - flowering and again three weeks after 1st spray
6.	Leaf defoliating beetles	Feed on leaves during night Season of infestation - June - July more in neglected orchards	a. Spray thiodan 0.05% (or) Monocrotophosb. Ploughing the soil and expose the grafts

4. Avoidance of Glut

Dipping the ber fruits in waxol 6% solution is observed to be effective in reducing the fruit weight loss and decay losses. The ripening percentage is also put under check by this treatment of waxol.

Treating the fruits with wax emulation and keeping them in perforated papers and polythene bags with wax emulsion treatment could extend the storage life of ber fruits. The storage life of ber cultivars Umran and Sanaur-2 could be extended to 10 days and 12 days respectively under ambient temperature while cold storage of 3°C and 85-90% RH ber fruits of umran variety could be stored upto 30 days.

Other than the above problems, some of the following cultural practices can be practiced to improve the yield and quality of ber fruits

a) Mix 5 kg of gypsum per pit followed by flooding one week before new planting of ber in saline soils.

b) Rootstock of Z*izyphus jujube* could be used against salinity as a biological reclamation of saline soils. *Zizyphus rotundifolia*, *Zizyphus nummaloria* are found to be resistant to salinity.

c) Seedlings of *Zizyphus mauritiana* can be raised (April) as root stock in polybags and then patch budded with commercial varieties so as to reduce the transplanting (August) shock and higher percentage of survival and establishment of new ber plantation.

d) In desertic condition a double walled earthen pot named as Jaltripti is used to irrigate the plants with less moisture evaporation loss which also reduces the mortality.

e) Irrigate the ber trees at fruit development stage *ie* from November to February. Micro catchment areas can be developed around ber plants in desert /dry areas.

f) Practice annual pruning of removal of one year old shoot in hot or dry season or when it sheds leaves or after harvest of fruits pruning not only improves fruit yield and quality, but also reduces fruit drop.

g) Interculturing *ie* stirring of soil below the canopy after pruning helps to expose the hibernating pupae of major insects, pests of ber. This operation also helps the capillaries to check the evaporation losses.

h) The ber plantation should be kept clean by removing weeds and wild species of *Zizyphus* as it acts as an alternate host for major pests and diseases.

i) Ber responses well to application of organic manures and inorganic fertilizer both as soil and foliar application. Application of 30- 50 kg of FYM: 250 of N and P_2O_5 and 50 g of K_2O in split doses are recommended for grown up tree more than 5 years. Foliar application of 2% urea improves fruit quality, interms of improved TSS and decreased acidity.

j) Planting of more than two or three varieties of ber is advisable in new plantations of commercial varieties of ber which are self incompatible.

k) Application of growth regulators viz GA_3 @ 10 -15 ppm concentration is found to improve the fruit set from 27- 80 percent.

l) Grade the harvested ber fruits based on their maturity. Other wise the mixing of over ripe fruits which are less crispy and juicy affects other fruits and cause deterioration of fruits which would fetch very little market price.

m) Dip the harvested fruits in wax oil 6 % solution to reduce the fruit weight loss and decay loss which also checks fruit ripening.

n) Pack the waxol treated ber fruits in perforated poly bags or paper bags to extend the storage life under ambient temperature.

o) Under cold storage of 3° C temperature and 85- 90 % RH storage life of ber up to 30 days is possible without any shrinkage.

Management of Production Constraints in Pomegranate

Pomegranate is commercially grown for its sweet and acidic fruits, which are used both as dessert fruit and processed products such as bottled juices, syrup and jelly. Dried seeds called as ‘Anardana’ have medicinal value and are used as condiment. Bark and rind also have medicinal value.

Pomegranate is native to Iran and from there it has spread to Asia. The genus *Punica* has three important species viz., *Punica granatum* (tropical and subtropical) and *P. protopunica* (temperate). In the recent years it has gained momentum as an export potential crop. It is not only considered as an important arid fruit crop but also as commercially important fruit crops in other fruit growing regions of India.

Climate and soil

Pomegranate has a versatile adaptability to wide range of climatic conditions up to an elevation of 1000 m MSL. It is a winter hardy and drought tolerant crop. It performs well in semi arid and arid climate were cold winter and hot summer prevails. In low temperature areas it acts as deciduous tree while under tropical and subtropical conditions it behaves as a evergreen or partially deciduous tree. It requires optimum temperature of 38° for fruit development.

Pomegranate is a hardy plant and can be grown in diverse type of soils. It performs well in deep loamy or alluvial soils although it thrives well on comparatively poor soils. It tolerates slightly alkaline to limy soils.

Propagation

Pomegranate is propagated commercially by hard wood stem cuttings prepared from one year old shoots. Cuttings are treated with IBA 3000 ppm and kept under mist chamber to get the highest percentage of success (90 percent). It may be propagated through air layering or gootee also.

Planting

In general, June-July is the best season for planting. In square and hexagonal system of planting, a spacing of 5 x 5 m is generally practiced for pomegranate. However, plant spacing of 5 x 2 m is also practiced initially and later thinned to 5 x 4 m spacing in new plantation. A closer spacing of 3 x 2.5 m or 4 x 2 m can also be practiced without any reduction in yield.

Training

Pomegranate is trained as a single stem plant, as the method of training in the initial years of planting. Training the trees with 3 or 4 main trunks is encouraged to avoid the bushy nature of plant (for easy inter cultural operations) and also to protect against the damage of stem borer.

Pruning

Pruning is practiced annually as removal of dead and dried branches and water suckers during winter (October – December).

Annual pruning of one year old shoots during winter (December – January) that dormant season has to be encouraged to maintain the balance between vegetative and reproductive growth of grown up tree of pomegranate.

Irrigation

Regular irrigation is necessary for newly planted pomegranate plants till their establishment. Later irrigation is essential during flowering and fruit development as irregular moisture availability would result in dropping of flowers as small fruits. It may also cause fruit cracking on mature fruits. Though bed or basin system of irrigation is followed, nowadays, drip irrigation is practiced as a water saving technique.

Intercropping

During the first 5-6 years of planting, vegetable crops like onion, cole crops, brinjal, cow pea and green manure crops can be grown as inter crops to earn profit and also improve soil fertility status.

Manuring

Though pomegranate is cultivated in shallow soils and medium type of soils it responds well to manuring and fertilizer applications. An adult tree can be supplied with 50 kg FYM, 625 kg N, 250 kg P_2O_5, and 250 kg K_2O per tree twice in a year, coinciding with after pruning and rainy season which is proved to be effective on improving the yield and quality of pomegranate.

Age of tree (year)	FYM kg/tree	N(g)	P(g)	K(g)	Doses
1.	10	250	125	125	12-every month
2.	20	250	125	125	3-Jan, June and September
3.	30	500	125	125	3-Jan, June and September
4.	40	500	125	250	2 at pruning and flowering
5.	50	600	250	250	2 at pruning and flowering

Crop regulation

Flowering in pomegranate is several times in a year under hot climate of South India and several distinct flushes of flowering occur in sub tropical climates also.

It can be achieved by regulating the flowering either through cultural practices like 'bahar' treatment or through 'blossom thinning'. In bahar treatment, encouraging flowering during June-July and fruit harvest during December-January is the most preferred practice by progressive pomegranate growers so as to get premium price of good quality fruits.

Harvest

An adult tree bears 125-150 fruits in a year normally. Harvest the fruits manually with help of fruit harvester so as to reduce the physical damage to the fruits.

Major production constraints of pomegranate and their management

Crop regulation, fruit cracking, pomegranate decline, diseases and pests are some of the production constraints in pomegranate.

1. Bahar treatment

There are three main seasons of flowering in pomegranate.

a. January-February (Ambe bahar) **-** high rainfall and humid areas.

b. June-July-Mrig bahar**-** preferred in dry areas.

c. September-October-Hasta bahar.

Ambe bahar is preferred to avoid spoilage of fruits owing to disease and pest infestation during monsoon period. Mrig bahar, is preferred to develop fruits with dark pink coloured arils since the fruit matures during winter which is preferred by growers to get premium price. Keep only solitary flowers and fruits that are nearer to main axis. After getting set of fruits of desired number as per the size of tree, remove all the flowers coming there after.

Staggered cropping can be induced in June. However, February cropping is suggested as to best in quality followed by October flowering and December cropping.

To force Mrig bahar flowering,

a) Withhold irrigation from December –April to May

b) Form basin around the trees and plough interspaces

c) Apply manures and fertilizers of recommended dose

d) Irrigate twice or thrice till during fruit development

e) Keep only solitary flowers and fruits

f) Deblossom excessive flowers

2. Fruit cracking

It is a serious problem in pomegranate which occurs more frequently in dry atmosphere. The cracked fruits are though sweeter, lose shelf life and become unfit for transport or shipment as they are liable to rot. The main reason for the fruit cracking in pomegranate is sudden change in the moisture content (Cheema *et.al*. 1954) especially during fruit ripening. According to Pant (1976) increase in air temperature is the main cause for fruit cracking.

It is also assumed that deficiencies of Calcium and Boron are also related to fruit cracking. The varietal difference in fruit cracking was also observed by Varshishta (1982) and he reported that fruit cracking is more in Jodhpuri varieties than Sharanpuri (UP) varieties. The cultivar Appuli was found to be resistant to fruit cracking of pomegranate. The strains PS75, K-3 were reported to be tolerant to fruit cracking. Rind thickness and texture of fruits in various cultivars seems to influence intensify of cracking.

To reduce this problem, adequate and regular irrigation and inter culture throughout the bearing period have to be adopted. It is also reported that application of 5% pionlene vapour gourd 4-5 weeks before fruit harvest could found to reduce the fruit cracking spraying of GA_3 @ 120 ppm concentration was also found to reduce to fruit cracking.

3. Pomegranate decline

In recent years, pomegranate decline is very much reported by the progressive growers even after their continuous vigilance crop. The incidence of pomegranate decline is indicated by slow and poor growth, leaf fall, drying of twigs and branches, poor flower and fruit set and development and then final death of trees.

The following recommendations were finally arrived at to check the incidence of pomegranate decline.

a. Planting of pomegranate in light soils upto 45cm depth.

b. Spacing should be followed as 4.5m x 3.0m

c. Regular interval of irrigation should be adopted.

Drip irrigation is preferred. If not possible, irrigate the field based on evaporation rate of that locality. Interval of irrigation should be 8-10 days in summer, 13-14 days in rainy season and 17-18 days in winter.

d. To protect against pest and diseases follow the IPMs strategies

e. Drench the soil with 0.1% carbendazim @ 5 litres per tree + soil application of 2.5 kg of Trichoderma + 100 kg of FYM per ha.

f. Double the dose of soil drench of 0.1% Carbendazim + Trichoderma + FYM to the affected trees.

g. Apply FYM @ 2kg per tree for every two months.

h. Apply neem cake @ 2kg of the time of bahar treatment and after 3 months apply 40 kg of phorate (10G) to soil.

i. Apply 0.05% Lindane or 0.1% Chlorpyriphos to control shot hole borer. Also drench the same chemicals + Blitox as soil drench @ 5 litres per tree near root zone.

j. To control stem borer inject, Fenverlarate @ 5ml or Dichlorovas @ 10 ml per tree in the holes on stem and plug it with mud.

4. Diseases of Pomegranate

S.No.	Disease	Symptom	Control
1.	Bacterial leaf spot-*Xanthomonas punicae*	Black colored in definite spot on leaves & fruits	Dithane M-45-0.3% or COC 0.1%
2.	Leaf spot *Pseudocercospora punicae*	Black colored in definite spot on leaves & fruits	Dithane M-45-0.3% or COC 0.1%
3.	Fruit spot-*Drecheslora rostrata*	Irregular spot with greenish yellow border on fruits. seed and aril brown in color	a. Dithane M-45-0.5%b. Removal of affected branches at pruning
4.	Fruit rot (dry rot) - *Phomopsis* spp	Yellow or black spot on fruits near point of attachment. depression on fruits	a. Dithane M-45-0.5%b. Removal of affected branches at pruning
5.	Post harvest diseases *Aspergillus* rot-*Aspergillus* spp, *Pencillium* rot-*Pencillium* spp, *Botryodiplodia* rot - *Botryodiplodia* spp	Infection on injured fruit only	2, 4-D @ 500 ppm as pre infection dip + spray sulphur on packing materials
6.	Soft rot - *Rhizopus* spp	Infection on injured and uninjured fruits	Dithane M-45-0.5% or COC 0.1% or Blitox 0.5%

5. Pests of Pomegranate

S.No.	Pest	Symptoms	Control measures
1.	Pomegranate butterfly or fruit borer-*Virachola isocrates*	Feed on fruit pulp - fruit rot and drop-bad smell, excreta near entry hole	a. Metacid or carbaryl-0.2% or phosphomidan-0.03% at flowering and fruit development, b. Cover with polybags
2.	Bark eating caterpillar-*Indarbela tetronis*	Larvae feed on bark, hide in tunnels,excreta +chewed materials hang on affected part	a. Keep the orchard cleanb. Collect and kill the larvac. Insert a cotton swab of kerosene treat the holes with fenvelarate 0.1%, spray 0.1 monocrotophos

S.No.	Pest	Symptoms	Control measures
3.	Short hole borer	Feed on bark and construct gallies with minute pin hole on stem	a. Clean the hole extract the insect b. Insert a cotton swab of kerosene, treat the holes with fenvelarate 0.1%, c. Spray 0.1 % monocrotophos
4.	Fruit sucking moth-*Orthesis* spp	Caterpillar feed on leaf of host, moth feed on fruit during night-fruit rot	a. Use repellents-citronella oil b. Cover the fruits with polybags c. Use poisonous bait-malathion +jaggeryd. Spray dichlorovas- 0.1%e. Collection and destruction of host,affected and fallen fruits
5.	Mealy bugs, Scale insect and white fly	Suck the cell sap of fruit and foliage Secrete honey dew, develop sooty mould	a. Collection and destruction of damaged parts b. Use predators- australian lady bird beetle, c. Egg parasitoidd. Verticillium fungus
6.	Aphids & thrips	Suck the cell sap of fruit and foliage Secrete honey dew, develop sooty mould, affected parts disfigured and discolored	Spray Dimethoate or Monocrotophos 0.03%
7.	Nematodes - *Helicotylenchus Xiphinema, Meloidogyne*	Feed from outside the roots, secondary infection by fungus Feed on roots and develop galls	Apply neem cake at the rate of 2kg / tree + carbofuran 3G-20gs / tree

Co strai ts i Eroductio o(7ruit Crops i Arid a d Wastela ds

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Introduction

The agricultural production is significantly influenced by climatic constraints, change and variability. Out of the 142 million hectares gross cultivated area in the country, over 100 m ha are rainfed. In fact all over the globe, 25% of the arable land is drought affected, 22% shallow soils, 14% freezing and 11% excess water. Thus only 9-10% of the arable land, not prone to any stress is available for cultivation.

1.1 Arid and wastelands

The arid lands have low and erratic rainfall, high evaporation and extremes of temperature. Though these lands have well defined monsoon system as compared to other deserts, desertification may occur due to miss management of ecosystem. These lands are characterized by wind erosion and transportation of soil particles.

1.2 Characteristics of wastelands

The lands in which cultivation practices were not done for the past three years and which are rainfed, are classified as wastelands. The wastelands have less than 20% biological productivity drought prone, dependent on rains for moisture. The following are the factors, by which the wastelands area got increased.

- Over-exploitation of land resources by hybrid varieties, inorganic fertilizers and pesticide use.
- Wind erosion, soil erosion, and reduction in water harvesting area, destruction of forests, forest fire, salinity and alkalinity.
- There is lowering of ground water table by indiscriminate pumping of water from bore wells
- When the area is receiving 750 mm and less rainfall, there is every possibility for crop loss resulting in wastelands.

1.3 Opportunities in wastelands

The farmers in the rainfed regions are resource poor. Crop production and productivity fluctuate year to year due to vagaries of weather. Rainfed areas are not quite competitive; however there are some niche areas for exploitation. Rainfed areas offer excellent opportunities for fruit crops.

1.4 Wastelands in Tamil Nadu

The total geographical area of Tamil Nadu state is 130 lakh hectares. Of this 24 lakh hectares are wastelands of one type or the other. Wastelands are degraded and are presently unutilized due to different constraints. They can be classified as

i. Wastelands suitable for cultivation
ii. Wastelands not suitable for cultivation, which includes rocks, deserts and salt, affected soils.

Certain fruit crops can be cultivated in the first category of wastelands. The potentialities of these fruit crops, trees and their promotion in wastelands have immense possibilities and can be exploited in a larger way. Ameliorating these wastelands will enable increasing of agricultural production and also generate employment in agricultural and inter-linked sectors.

2. Weather

The weather during cropping season strongly influences the crop growth and it accounts for 2/3rd (67%) of the variation in productivity, while other factors including soil and nutrient management accounts for 1/3rd (33%) of the productivity. The importance of weather assumes a greater significance in rain fed regions. The elements of weather that characterize the agro climatic environment act as a natural resource influencing the cropping are rainfall, temperature, sunshine, wind regime, humidity, and radiation. The choice of cropping system is mostly governed by the length of the growing period. Considering the above points it is advisable to plant fruit crops and multipurpose trees in the arid and waste lands.

3. Suitable crops

The fruit trees and multi purpose Tree Species (MPTS) can be grown in these areas. Fruit trees like ber, sapota, and custard apple are suitable for rainfed vertisols. In red soils, mango, sapota, pomegranate can be grown in arid lands. In wastelands, aonla, cashew, tamarind, jamun and sita can be grown under rainfed conditions with protective irrigations. The trees grown in dry lands take 5-8 years to cover the inter space and suitable intercrops with rain fed annual crops can be grown.

Mostly dryland farmers do not grow surplus crops for sale to provide enough cash income to meet family needs. The rainfall in the arid and semi arid lands are meagre with uneven distribution. Hence drought tolerant crops have to be selected.

Table 1: Crops suitable for arid and waste lands

Category	Classification	Crops
Fruit crops	Red soil with minimum irrigation.	Mango - *Mangifera indica,* Guava - *Psidium guajava,* Sapota - *Achras sapota,* Pomegranate - *Punica granatum*
	Rain fed regions	Ber - *Ziziphus mauritiana,* Cashew - *Anacardium occidentale* Tamarind - *Tamarindus indica,* Anona - *Annona squamosa,* Aonla - *Phyllanthus emblica*
Multi purpose tree	Semi arid red soils Semi arid black cotton soils	*Albizia lebbeck, Leucaena leucocephala, Acacia auriculiformis, Acacia nilotica, Acacia procera, Hardwichia binata, Sesbania* spp. *Azadirachta indica*
	Saline & alkaline soils.	*Acacia nilotica, Dalbergia sisoo, Pongamia pinnata, Albizia procera*

4. Soil management

Nature takes about 110 years to form 1 cm thick top soil and it could be brought down to 11 years by intensive cultivation practices. In arid and wastelands, the soils are not productive. They are less in nutrients and are affected by wind erosion. Saline and alkaline conditions are more prevalent. This necessitates soil conservation in these areas. The following soil conservation approaches have to be followed (Shanmugasundaram, 2005).

4.1 Contour bunding

The construction of small bunds across the slope of the land on a contour is contour bunding. The long slope is cut into a series of small ones and each contour bund acts as a barrier to the flow of water. Contour bunds are constructed in relatively low rainfall areas, having an annual rainfall less than 600mm, particularly in areas having high textured soils.

4.2 Graded bunds

Graded bunds are constructed in medium high rainfall areas having an annual rainfall of 600 mm and above and in the lands having slopes between 2% and 6%. These bunds are provided with a channel if necessary.

4.3 Contour trenches

Contour trenching is excavated trenches along a uniform level across the slope of the land in the top portion of catchments. Bunds are formed down stream along the trenches. The main idea is to create more favorable moisture conditions and thus accelerate the growth of planted trees.

4.4 Staggered trenches

Staggered trenching is excavating trenching of shorter lengths in a row along the contour with interspace between them. In Tamil Nadu, contour and staggered trenches are adopted in high rainfall hilly areas of lands with slopes steeper than 3%.

4.5 Bench Terrace

Bench terracing is one of the most popular structural soil conservation practices adopted by the farmers of India and other countries for ages on sloping and undulating lands. Intensive farming can be adopted in these bench terraces.

4.6 Contour stone wall

In this cut stones of size around 20 – 30 cm are dry packed across the hill slope to form a regular shape of random rubble masonry without mortar.

5.0 Water Management

In arid and wasteland water is a major constraint. The ground water potential is low and the available water may also be saline or alkaline. Hence, the available rainfall should be harvested in an effective way. Following are some of the successful rain water harvesting techniques that can be adopted in arid and waste lands.

5.1 Farm ponds

Farm ponds are small tanks constructed to collect surface run off. Some ponds get water from surface run off and some from ground water seeping into the pit. The water stored can be used directly for irrigation, for the cattle, fish production etc.

5.2 Percolation ponds

Percolation ponds are small water harvesting structures constructed across small natural streams and water courses to collect and impound the surface run off, during monsoons.

5.3 Drainage line treatments

The soil gets eroded through rain splash in the form of sheet, rill and gully erosion. Unattended development of rills leads to formation of gullies. The best way to control the gullies is to vegetate the surface of the gully to protect it from further development. Temporary gully control structures like brush wood dam, loose rock dam, wire woven dam etc, made of cheap and locally available materials can be established.

5.4 Drip irrigation

The fruit crops in arid and wasteland can be grown under drip system of irrigation. Drip / micro irrigation has emerged as an ideal technology, through which the required amount of water is applied to the root zone of the crop by means of a network of pipes in the form of drippers. The efficacy under micro irrigation is as high as 80 – 90 percent. The system permits the use of fertilizers, pesticides and other water soluble chemicals along with the irrigation water at optimum levels.

6. Integrated nutrient management

The arid and wastelands are poor in nutrition. The nutrient status is aggravated due to frequent drought as well as run off. The critical soil fertility related issues in drylands are runoff, poor organic matter, poor physical properties and management practices. To grow fruit crops in this region it is essential to manure organically. The constraints of nutrient management can be overcome by the application of proper manures / fertilizers as per the recommendations given below.

Mango

Manures / Fertilizers (Kg/Plant)	1 year old	Annual increase	6^{th} year onwards
FYM	10	10	50
N	0.20	0.20	1.0
P	0.20	0.20	1.0
K	0.30	0.30	1.5

Manures and fertilizers may be applied during September-October, 45-90 cm away from the trunk up to the peripheral leaf drip & incorporated.

Guava

i. FYM - 50 Kg, NPK - 1Kg each per tree in two split doses during March and October.

ii. Urea 1% & Zinc sulphate 0.5% can be sprayed twice a year during March & October.

iii. Boron deficiency can be corrected by spraying 0.3 % borax during flowering and fruit set stage.

iv. Spraying of micronutrients *viz.* Zn So_4, Mg So_4 and Mn So_4 @ 0.5% and cu So_4 and Fe So_4 @ 0.25% plus Teepol @ 1ml per 5 lit of solution on various stages viz., (i) New Flush, (ii) Flowering (iii) one month after first spray and (iv) Fruit set is recommended.

Sapota

Manures / Fertilizers (Kg/Plant)	1 year old	Annual increase	6th year onwards
FYM	10	10	50
N	0.200	0.200	1.000
P	0.200	0.200	1.000
K	0.300	0.300	1.500

Manures and fertilizers may be applied in September - October, 45 cm away from the trunk up to the leaf drip and incorporated.

Pomegranate

Manures / Fertilizers	1st year	2nd year	6th year onwards
FYM (Kg/Plant)	10.0	20.0	30.0
N (g/ Plant)	200	400	600
P (g/ Plant)	100	250	500
K (g/ Plant)	400	800	1200

Ber

Manures / Fertilizers	1st year	2nd year onwards
FYM (Kg/Plant)	10.0	30.0
N (g/ Plant)	200	600
P (g/ Plant)	100	500
K (g/ Plant)	400	1200

Manuring has to be done immediately after pruning. KNO_3 may be sprayed thrice at monthly intervals in January, February and March.

Aonla

Manures / Fertilizers	Bearing Tree
FYM (Kg/Plant)	10
N (g/ Plant)	200
P (g/ Plant)	500
K (g/ Plant)	200

Manuring is to be given immediately after pruning.

Cashew

Manures / Fertilizers	I year	II year	III year	IV year	V year onwards
FYM (Kg/Plant)	10	20	20	30	50
N (g/ Plant)	70	140	210	280	500
P (g/ Plant)	40	80	120	160	200
K (g/ Plant)	60	120	180	240	300

Fertilizer application may be done during November - December in East coast areas, where ever possible the fertilizers may be applied in two equal split doses during June - July and October - November - periods.

7. Horticultural management

Appropriate and timely horticultural management has to be done to fruit crops grown in arid and wastelands.

Table 2. Canopy management in fruit crops

Fruit crops	Canopy management
Mango	• Overlapping, intercrossing, diseasesd, dries and week branches has to be pruned during august-september, once in three years. • Root stock sprouts have to be removed
Guava	• Pruning of past season terminal growth to a length of 10 to 15 cm is to be done during Sep-Oct and Feb-March • Erect growing branches ar to be bent by tying on to pegs
Supporta	• Root stock sprouts, water shoots, criss cross and lower branches has to be removed
Pomegranate	• The past season shoot has to be pruned by removing 1/3rd of the length
Ber	• Root stock sprout has to be removed and a straight stem up to 75 cm from the ground level has to be trained • Pruning in Feb-March to remove crowded branches
Aonla	• Main branches should be allowed to appear at a height of 0.75 to 1.0m above the ground level • Plants are trained to modified central leader system • During March- Apr pruning anf thining of crowded branches may be done
Cashew	• Trunk is developed to a height of 1m by removing low lying branches
Tamarind	• Root stock sprouts are to be removed • Dry and diseased parts are to be removed

8. Conclusion

The arid and waste lands are unutilized and unproductive. The resources are poor in these lands. However, fruit crops and multi purpose tree species can be grown in these areas. There are certain constraints in production of fruit crops. With proper identification of crops suitable for area, proper soil conservation, water management practices and the available soil moisture can be conserved and fruit crops can be effectively grown. Integrated approach on nutrient management and proper and timely horticultural practices will minimize the production constraints and will improve the yield.

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Biotech ological Approaches i Overcomi g Eroductio Co strai ts i 7ruit Crops

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Introduction

Fruit crops are vegetatively propagated perennials. Conventional genetic improvement of most species of fruit crops face a range of problems. This include the long juvenility period of some species, seedlessness, frequent inter and intra specific incompatibility, high heterozygosity, sterility and the presence of some specific traits only in wild species. These characteristics make conventional breeding techniques difficult, expensive and time consuming (Mehlenbacher, 1995). Alternatively, recombinant DNA (genetic engineering) approach is more precise in correcting the deficiencies in commercial cultivars or root stocks without disturbing their desirable genetic makeup (Schuerman and Dandekar, 1993).

Genetic engineering for pest and disease resistance

Virus resistance

The plant viruses reduce both the quality and quantity of crop yield by direct damage to plant. In several fruit crops, virus disease represents a particular problem, for example in grapes, the grape vine chrome mosaic virus (GCMV) in *Prunus* sp., the grape fan leaf virus (GFLV) and in papaya the papaya ring spot virus (PRSV) (Gonsalves, 1998). Transgenic resistance in fruit crops can be obtained by pathogen derived resistance (PDR). PDR is operated in plants when genes from the virus is cloned and transferred to host genome (Sanford and Johnston, 1985). PDR is developed when the viral gene products or virus related sequences in the plant genome interfere with the virus infection cycle. Though many PDR strategies include coat protein (CP), antisense nucleic acids, satellite sequences, defective interfering molecules and non structural gene (replicase, protease and movement protein), antibiotics and interferon related proteins are available (Kaniewski and Lawson, 1998) for virus disease resistance, only CP mediated is successfully utilized in fruit crops.

One such a successful example is transgenic papaya expressing CP of PRSV against PRSV. The disease was first discovered on Oahu of Hawaii Island during 1945 and caused such severe damage that the papaya industry was relocated to Puna area of Hawaii in the late 1950s and early 1960s. In 1986, efforts were initiated to develop a virus-resistant transgenic papaya by transforming commercial lines of Hawaiian papaya with the CP gene of PRSV from Hawaii. By 1991, the team of Maureen Fitch, Jerry Slightom, Richard Manshardt and Dennis Gonsalves identified a transgenic line (55-1) that showed resistance under greenhouse as well as under field conditions. These plants were micropagated and established in a field trial in Oahu (1992). The importance of transgenic papaya was realized when PRSV was also discovered in Puna area on Hawaii Island, where 95% of Hawaii's papaya was being grown. From the 1992 field trial, two cultivars were developed and designated 'SunUp' and 'Rainbow'. 'SunUp' is homozygous for the coat protein gene while 'Rainbow' is an Fl hybrid of 'SunUp' and the nontransgenic 'Kapoho'. A 1995 field trial in Puna conclusively showed that 'SunUp' and 'Rainbow' were resistant under prolonged and heavy disease pressure. Licenses to commercialize the transgenic papaya were obtained by the Papaya Administrative Committee in Hawaii by 1998. The transgenic fruit is currently sold in international market such as Canada and throughout the United States (Gonsalves, 2004). There are other reports that virus-resistant transgenic plants expressing CP in many fruit crops (Table 1) but these are yet to be commercialized.

Table 1. Genetic modification of fruit crops for virus resistance

Fruit crops	Gene(s)	System	Explants	Resistance in plants	Reference
Apricot *(P. armeniaca)*	CP-PPV	A.t	Cotyledons of immature embryo	PPV	Machado *et al.* 1992
Papaya *(Carica papaya* L.)	CP-PRV-4	PB	Zygotic embryos, hypocotyls	some PRV strains	Fitch et al. 1992 Cheng e*t al.* 1996
Papaya	CP-PRSV	PB	Embryogenic calli	PRV	Fitch *et al.* 1998
Plum *(P. domestica)*	CP-PPV	A.t	Hypocotyls	PPV	*Scorza et al. 1994 Ravelonandro et al. 1997*
Plum *(P. domestica)* L cv Bluefree	CP-PPV	A.t	Leaf discs	PPV	Machado *et al.* 1994

PPV-plum pox virus (poty virus group); PRV/PRSV – papaya ring spot virus; *A.t – Agrobacterium tumefaciens;* PB- particle bombardment

Fungal resistance

Among diseases, fungi are the main cause of yield loss in fruit crops. They are controlled by several traditional techniques including quarantine, sanitation, breeding and clonal selection of resistant varieties and application of fungicides. However, resistance cultivars, with the onset of new strains of virulent pathogens, tend to become susceptible over time. In addition, the unrestrained use of fungicides result in enhanced production costs, degradation of environment and induction of new forms of resistance within the pathogens, consequently forcing the development of new pesticides. These problems have encouraged the search for biotechnological solutions to combat fungal diseases. At present, research is focused on identifying the genes involved in resistance. Several proteins have been reported with antifungal activities which are otherwise called as pathogenesis-related proteins (PRs). Plant *b*-1,3 glucanases (PR-2) and chitinases (PR-3) represent potential anti-fungal activity *in vitro* (Mauch *et al.*, 1988). In addition *b*-1,3 glucanases release glucosidic fragments from both the pathogen and host cell walls which could act as signals in the elicitation of host defences (Takeuchi *et al*., 1990). The identified anti-fungal proteins are isolated from plants as well as from fungus such as *Trichoderma harzianum* (Melchers *et al.*, 1993). The transgenic fruit crops expressing the anti-fungal proteins are summarized in Table 2.

Table 2. Genetic modification of fruit crops for fungal disease resistance

Fruit crops	Gene(s)	System	Explants	Resistance in plants	Reference
Apple (Malus domestica)	Endo-chitinase	A.t	Leaf	Against apple scabVenturia inequalis	Norelli et al. 2000
Apple (M. domestica) Borkh McIntosh	ThEn-42	A.t	Maternal	Apple scab	Bolar et al. 2000
Banana (Musa spp) Dwarf Parfitt (AAA-Cavendish)	-	Irradiation	Shoots	Fusarium wilt-race 4	Smith et al. 1995
Kiwi fruit (Actinidia deliciosa) cv. Hayward	osmotin	A.t	Maternal	Botrytis sp.	Rugini et al. 1999

ThEn-42 –endochitinase from *T. harzianum*

Bacterial resistance

Bacterial diseases cause huge yield loss on both tropical and temperate tree crops with effects varying from death of entire plant to loss of quality of fruits. Important bacterial diseases of fruit trees are fire blight caused by *Erwinia amylovora* (apple, pear and rose), bacterial blight and canker, *Pseudomonads syringae* and canker of citrus (*Xanthomonas citri*). Research on resistance to bacterial disease has focused on genes producing the anti-microbial proteins like lytic peptides (cercopins, attacins and synthetic analogues shiva-1, SB-37), and lysozymes (egg white, T4 bacteriophage and human lysozyme). Transgenic plants expressing these anti-microbial proteins are summarized as follows (Table 3).

Table 3. Genetic modification of fruit crops for bacteria disease resistance

Fruit crops	Gene(s)	System	Explants	Resistance in plants	Reference
Apple *(M. domestica)* M26	AttE	A.t	Leaf segment	*E. amylovora*	Norelli *et al.* 1994
Apple *(M.domestica)* cv. Galaxy	AttE; T4 lysozyme	A.t	Leaf segment	*E. amylovora*	Ko *et al.* 1999
Apple *(M. domestica)* Bork, cv. Royal Gala, M7	AttE ; SB-37 ; Shiva-1	A.t	Leaf segment	*E. amylovora*	Norelli *et al.* 1999
Apple *(M. domestica)* M26	AttE	A.t	Maternal	*E. amylovora*	Norelli *et al.* 1994
Apple *(M. domestica)* Bork	cercopin MB39	A.t	Maternal	*E. amylovora*	Liu *et al.* 2001
Pear *(Pyrus communis)* cv. Passe Crassane	AttE	A.t	Leaf segment	*E. amylovora*	Reynoird *et al.* 1999
Grape *(Vitis vinifera)*	pgip	A.t	callus	*Xylella fastidiosa* causes Pierce's disease	Aguero *et al.* 2003

AttE- lytic protein attacin E ; *pgip* - Polygalacturonase-inhibiting proteins A.t. : *Agrobacterium tumefaciens*

Nematode resistance

Many fruit crops are attacked by nematodes of the species of *Meloidogyne* spp., *Xiphinema* spp., and *Longidorus* spp. Nematodes are very difficult to eradicate from the infected soil and also the control by nematicides is not appropriate due to huge expenses and hazards. Plant responds to infection with a variety of defense strategies including production of phytoalexins, deposition of lignin like materials, accumulation of hydroxyl, proline rich glycoproteins, expression of PR-proteins and with an increase of lytic enzymes. Potential anti-nematode genes have been reported and seem to be effective when they are constitutively expressed in plants.

Examples:

- gene over expressing collagenases which damage the nematode cuticle (Havstad *et al*. 1991)
- exotoxin of *Bacillus thuringiensis* (Devidas and Rehberger, 1992)
- anti-nematode monoclonal antibodies (Schots *et al.* 1992)

Molecular information on nematode resistance is limited and transgenic approaches by exploiting above nematode resistance genes need to be developed in fruit crops.

Insect and pest resistance

Genetic engineering offers new approaches to more rapid implementation of anti-insect strategies in fruit crops. Several plants have been engineered with the aim of killing phytophagous insects by following strategies

- genes encoding insecticidal crystal protein from *B. thuringiensis*
- proteinase inhibitors
- lectins
- *a*-amylase inhibitors
- chitinases
- polyphenol oxidases and peroxidases
- lipoxygenases
- ribosome inactivating proteins (RIPs)

Among the above techniques crystal proteins and lectins were successfully employed in fruit crops.

Genes encoding insecticidal crystal protein from *B. thuringiensis*

Some strains of *B. thuringiensis* have been known for insecticidal activity. This activity is due to their insecticidal crystal proteins which are toxic for several important insect pests of fruit crops. Genes encoding these crystal proteins have been cloned from *B. thuringiensis* and are referred to as cry genes (*cry1Aa, cry1Ab* and *cry1Ac*). They have been transferred into several fruit crops including apple, grapes and walnut (Table 4).

Table 4. Genetic modification of fruit crops for insect resistance

Fruit crops	Gene(s)	System	Explants	Resistance in plants	Reference
Apple *(M. domestica)* cv Greenleaves	Cry1Aa	A.t	Leaf segment	Lepidoptera	Dandekar, 1992
Apple *(M. domestica)* cv Greenleaves	CpT1 :Cry1Aa	A.t	Leaf segment	LepidopteraColeoptera	James *et al.,* 1992; 1993
Grape *(Vitis vinifera)*	Cry1Aa	A.t	Stem segement	Lepidoptera	Singh and Sansavini, 1998
Walnut *(Juglans regia)*	Cry1Ac	A.t	Somatic embryo	Lepidoptera	Dandekar *et al.,* 1998

Lectins

Lectins are proteins with specific carbohydrate binding activity and seems to have multiple role in plant physiology. Many of the over 300 purified lectins from seeds are toxic for animals. Some of them are toxic for coleopteran, lepidopteran, dipteran and homopteran insects (Van Damme *et al.* 1998). The exact mode of action of lectins against insect pest is not yet clear. However, an insect diet containing mannose specific snowdrop lectin (GNA) is found effective in reducing larval growth of coleopteran and in reducing fecundity of adults of peach aphids (Sauvion *et al.* 1996). Coghlan (1997) reported that transgenic grapes expressing *gna* had protection against lepidopteran pests.

Controlled ripening and shelf life

By regulating the activity of enzymes involved in fruit ripening, such as cell wall degrading enzymes poly galacturonase, or ethylene biosynthesis, it is possible to control or delay fruit softening and improve its shelf life.

Several strategies have been developed to control ethylene production in plant tissues by:

- antisense 1 amino-cyclopropane-1 carboxylic acid (ACC, precursor of ethylene) synthase (Oeller *et al.* 1991)
- ACC oxidase (Hamilton *et al.* 1990)
- reduction of ACC by over expressing in plants the gene of *Pseudomonas* sp. ACC deaminase, which converts it to *a*- ketobutyrate (Klee *et al.* 1991)
- lowering the substrate for ACC synthase by overexpressing the S-adenosyl methionine hydrolase (SAM ase) gene (Mathews *et al.* 1995)

Among fruit crops, only in peach (Trainotti *et al.* 1997), avocado (McGravey *et al.* 1990), grape (Robinson *et al.* 1997), sweet orange (Alonso *et al.* 1995) and strawberry (Wilkinson *et al.* 1995) attempts were made to control fruit ripening.

In our laboratory, efforts are being taken to transform banana genotypes of Grand Naine and Robusta with anti ripening genes *viz.*, antisense poly galacturonase and antisense ACC oxidase, to enhance the shelf life of the fruits.

Future perspectives

While much effort has been directed on developing efficient protocols to regenerate transgenic plants using reporter or marker genes, resistance to biotic stress and fruit ripening are receiving focus of research in recent years. There are also problems remain to be solved in fundament methodology including gene transfer and efficient protocols for regeneration for some fruit crops.

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Erecisio 7armi g i 7ruit Crops

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Precision farming is one of the most scientific and modern approaches to sustainable agriculture that has gained momentum towards the end of 20th century. Precision farming involves the application of technologies and principles to manage spatial and temporal variability associated with all aspects of horticultural production for improving crop performance and environment quality. Precision farming calls for an efficient management of resources through location specific hi-tech interventions. Hi-tech horticulture encompasses a variety of interventions such as microirrigation, fertigation, protected/greenhouse cultivation, soil and leaf nutrient based fertilizer management, mulching for *in-situ* moisture conservation, micropropagation, biology for germplasm, genetically-modified crops, use of biofertilizers, vermiculture, high density planting, hi-tech mechanization, green food, soil less culture, biological control etc. Utilisation of these interventions orchestrated together having the aim of achieving higher output in given time period leads to precision farming, which is largely knowledge driven.

Precision farming would involve the measurement and understanding of variability over time and space. Moreover, the system would use the information generated through surveys to manage this variability by matching inputs to conditions within fields using site-specific inputs. Thus, precision farming is technology enabled, information based, and decision focused. The enabling technologies of precision farming can be grouped into five major categories such as Computer, Global Position System (GPS), Geographic Information System (GIS), Sensors and Application Control. Some of the enabling technologies were developed specifically for agriculture and their origin date back more than 20 years. Availability of contiguous blocks of monocrops and equipments needed for the survey, recording and analysis on real time basis has made the precision farming technologies a reality in developed countries, where farm holdings are large, heavily equipment dependent.

Precision farming in the Indian context is still in its infancy stage. A vast amount of data on various aspects are available. However, application of precision farming as a package in the farmer's fields has received little attention. This is primarily due to lack of awareness about the potential for increasing productivity and improving the quality of produce with minimum use of inputs. Secondly, there has been no serious attempt in the past to promote this technology by any agency. The infrastructure available in terms of remote sensing and GIS are yet to be used effectively in promoting precision farming. Therefore, there is an urgent need to develop a package based on knowledge of soil environment and crop needs to enhance the efficiency of inputs to get higher output in given time frame.

Some of the other terminologies used for precision farming are Precision Agriculture (PA), Site Specific Farming (SSF), Site- Specific Management (SSM), farming-by-the-foot, Variable- Rate Technology (VRT) etc. The main objective of adopting precision farming in India is to improve agricultural production, quality of environment and economic status of the farmers.

Component and facilitator of precision farming

Computer and Internet

The computers and Internet are the most important components in enabling the precision farming possible as they are the main source of information, processing and gathering.

Global Positioning System (GPS)

The most common use of GPS in agriculture is for yield mapping and variable rate fertilizer/pesticide applicator. The GPS are important to find out the exact location in the field to assess the spatial variability and site-specific application of inputs. The GPS operating in differential mode are capable of providing location accuracy of 1m.

Geographical Information System (GIS)

The GIS is an organized collection of computer hardware, software, geographical data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information. It is rightly called as the brain of precision farming. It can help in agriculture in two ways. One is in linking and integrating GIS data (soil, crop, weather field history) with simulation models. Other is to support the engineering component for designing implements and GPS guided machineries (variable rate applicator) for precision agriculture.

Remote Sensing

Remote sensing holds great promise for precision farming because of its potential for monitoring spatial variability over time at high resolution. Remote sensing imagery for precision farming can be obtained either through satellite- based sensors or CIR video digital cameras on board small aircraft.

Steps in precision farming

The basic steps contributing to the concept of precision farming are assessing, managing and evaluation of variability.

Assessing variability

Assessing variability is the critical first step in precision farming since it is clear that one cannot manage what one does not know. The spatial variability in the field can be mapped by different means like surveying, interpolation of point samples, using high resolution aerial and satellite data and modeling to estimate spatial patterns.

Managing variability

Once variation is adequately assessed farmers must match agronomic inputs to known conditions using management recommendations that are site-specific and use accurate control equipment. The success of implementation of precision farming depends on how precisely, soil fertility, pest infestation, crop management with respect to biotic and abiotic variables and water are managed in the field and also how accurately the corrective actions are taken as per the variability noticed in the field.

Evaluation of precision farming

There are three important evaluation issues namely, economic viability, maintenance of environment and feasibility of technology transfer of precision agriculture. The economic evaluation focus on whether the documented agronomic benefits translate into value through market mechanisms. Environment evaluation focus on whether precision farming can improve soil, water and general ecological sustainability of our agricultural systems. Final and the foremost important issue is whether this technology of site-specific farming will work on individual farms and how far this technology can be transferred to other farmers.

Potential of precision farming in India

Although precision farming is a proven technology in many advanced countries of the world but its scope in India are limited. The constraints, which limit the scope for site-specific farming in India, are

i. Small size of land holdings
ii. Socio-economic status of Indian farmers
iii. Lack of success stories or cost-benefits studied on precision farming
iv. Knowledge and technological gap
v. Heterogeneity of cropping system in India
vi. Lack of market perfections
vii. Lack of local technical expertise
viii. Lack of data availability in terms of quality and cost.

However, many horticultural crops in India, which are high profit making, offer wide scope for precision farming.

Land and nutrient management in precision farming

The natural resources of the world are dwindling and the human population is increasing, along with increase in environmental pollution especially water, land and air. This is more in developing countries like India. Thus, with the increase in population there will be more requirement of food and fibre, but our land and water resources are diminishing. Hence precision farming is the urgent need of the day. The factors that contribute to higher growth and yield are crop variety, methods and amount of water, method of fertilizer application, agro-chemicals for pest management, effect of rootstock, root wetting, high density planting, environmental consideration and automated irrigation.

Strategic approaches of precision farming technology for improvement of fruit production

India is the second largest producer of fruit with total area of 3.8 million ha and total production of 45 million tonnes. Mango, banana, citrus, apple and guava occupy 80 per cent of the total area under fruits. India stands first in per cent production of many fruits like mango, banana, sapota and litchi.

India's past, present and projected population, fruit requirement, fruit production and deficit

Parameter	Year			
	1995	2000	2005	2010
Population, million	930	1000	1093	1209
Fruit requirement (Mt)	79.1	92.0	99.0	109.0
Fruit production (Mt)	32.9	34.0	46.0	53.0
Deficit (Mt)	-46.2	-58.0	-54.0	-56.0

Approaches and strategies for precision farming in mango

Mango is the important crop of India, accounting for about 39.16 per cent of total area under fruits and more than 23.09 per cent of total production in the country. India ranks first in the world for mango production and area under cultivation but with very low productivity as compared to Israel, Mexico and South Africa. In spite of large area under mango, per capita availability of mango is insufficient in India. Therefore, there is a need and great scope of boosting mango production for fresh consumption and processing into various products, both for domestic as well as export markets. Adoption of proper strategies, for overall increase in mango productivity is the present-day need to sustain commercial viability of the orchards.

Strategies for higher production

Selection of suitable variety

In India, more than thousand mango varieties are being grown in different parts of the country. Most of the Indian commercial cultivars are characteristically specific to geographical adaptation and their performance is satisfactory in a particular region. Therefore, selection of varieties for mango cultivation should be based on their suitability for a particular region. Selection of cultivars, for specific purpose, is one of the important factors. A regular bearing and high-yielding clone have to be recommended for commercial plantation.

Multiplication of genuine planting material

Establishment of healthy mother tree block with desirable characteristics of varieties is one of the important factors deciding the fate of the production efficiency in mango orchard. Therefore, high yielding clones of various commercial varieties should be selected for developing mother blocks. Adoption of suitable propagation technique standardized for respective region for making healthy planting material on a large scale for expanding area under mango cultivation is of importance. Use of salt tolerant rootstock, 13-1 should be tried in problem soils of India.

Water-use efficiency

Several factors, which determine the response of irrigation like soil type, season, region, stage of tree growth and varieties, should be taken into account while making irrigation schedules. For judicious water use, drip irrigation is being used in mango growing.

Balanced nutrition

Studies on leaf sampling techniques has shown that a sample of 6-7 months old. 30-40 normal and healthy leaves from middle of the shoot, representing almost all elevations on the crown from all directions reveals the correct nutrient status of the tree. Critical limits of N, P, K, Ca, Mg, S, Fe, Mn, Zn, and Cu have to be worked out. Optimum levels of leaf N have to be worked out for maximizing the production.

Beneficial effect on growth, flowering, fruiting and fruit quality can be achieved with foliar sprays. Application of organic manure in addition to balanced nutrient is important in the maintenance of soil fertility, which play vital role in tree growth and productivity.

Soil testing, as the sole basis for making fertilizer recommendations, has limited applicability with mango due to its large root distribution, perennial habit, rootstock effect and differential fruiting, soil and leaf analysis should, therefore, be complementary for determining the optimum dose of nutrients.

Manipulation of vegetative growth and flowering

The habit of growth, flowering and fruiting of mango cultivars should be thoroughly understood to safeguard the adversaries of cultivation. The seasonal cyclic changes of growth in shoot, root, flower, fruit and their development differ between cultivar and location. Environmental stimuli are dominant factors on yield potential of a mango cultivar. Tree canopy size of mango depends upon the variety, climate, edaphic conditions and cultural practices. Mango tree requires new vegetative growth in order to produce fruits each year. Temperature of 24-30°C is considered as optimum for proper growth. A cessation of vegetative growth is required to induce transformation from vegetative to reproductive phase. Therefore, canopy management and reproductive manipulation practices vary according to cultivars and climatic conditions. In tropics, with the understanding of flowering behavior along with advances in technology it is possible to manipulate the time of flowering and indirectly productivity and net returns.

High-density planting and tree canopy management

Poor yields experienced in Indian mango industry are partly due to wide tree spacing of conventional orchards with spacing ranging from 10 to 12 m between trees in rows and between rows. Canopies of these trees often take more than 10 years to fill the allocated space in the orchard row. This problem can be resolved with higher density plantings. Tree canopy management, especially size control, has become a priority for reducing production cost and increasing fruit yield and quality.

Alternate bearing management

Alternate bearing is a common phenomenon in majority of commercial mango cultivars, which is mostly because of existing antagonism between vegetative and reproductive phases. To manage this problem efforts can be made to regulate vegetative growth and flowering.

Rejuvenation of unproductive orchards

One of the reasons for the low productivity is due to large number of old mango orchards in the age group of 30-62 and above, has either gone unproductive or showing marked decline in productivity. This is attributed to overcrowded and intermingling of large branches and meager foliage, allowing poor light availability to growing shoots within the canopy. This renders them uneconomical. Severe pruning can rejuvenate these trees.

Managing disorders

This involves the management of various disorders like spongy tissue, malformation, black tip and leaf scorch

Pest and disease management

Efficient management of insect pests and diseases is important because they affect essentially every phase of growth and development. It is necessary to adopt IPM for important pest management. Monthly-integrated pest and disease management schedule can be maintained and followed.

Harvesting and post-harvest management

An improved method of harvesting has to be adopted. Alternative packaging containers such as corrugated cardboard package can be used. Precise management of post harvest handling has to be followed.

Precision farming of banana

Banana is one of the few crops in India, where hi-tech and precision farming techniques have been successfully practiced with full advantage. Introduction of improved variety suitable for processing and export, micro propagation, crop geometry, drip irrigation, fertigation, mulching, green manuring, recycling of banana waste, organic farming, proper hygiene of banana plantation through integrated disease and pests management, processing to puree transfer technology, training, participative demonstration etc., are some of the aspects responsible for the increased productivity.

Precision farming of guava

Guava is considered to be one of the exquisite, nutritionally valuable and remunerative crops. Guava fruits are used for both, fresh eating and processing. The precision technologies for improved production include selection of varieties, multiplication of genuine planting material and establishment of guava orchard.

Under establishment the factors like planting techniques, training and pruning, high density planting, rejuvenation of old plantation, growth and development, crop regulation, weed control, irrigation, inter cultivation, nutrition, fertilization and judicial management of deficiencies, pest and diseases and harvesting are taken into account.

Precision farming of papaya

Papaya is widely grown in tropics and India is the largest producer in the world. The precision technologies for improved production include selection of varieties, propagation and nursery production, planting season, spacing, sex expression and thinning, irrigation management, intercrop, plant protection and harvesting.

Precision farming of aonla

Aonla or Indian gooseberry is indigenous to Indian subcontinent. The precision technologies for improved production include selection of varieties, multiplication of genuine planting material, planting techniques, training and pruning, Manuring and fertilizer application, efficient water management, mulching, pest and disease management, harvesting and post harvest management.

Co strai ts i Microrirrigatio a d 7ertigatio i 7ruit Crops a d their Ma ageme t

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Introduction

Tamil Nadu is one of the water-starved states whose per capita water availability is less than the national average. The State's endowed irrigation potential in per capita terms is only about 0.08 hectare compared to all India average of 0.17 hectares. The annual available water resource per capita in Tamil Nadu is estimated at 600 m^3 which is quite low compared to 4000 m^3 , the national average.

Of the two major sources of irrigation water *viz.*, surface and ground water, the surface water potential of about 2.4 million hectares has almost been fully tapped since late sixties. This has led to increasing pressure on groundwater exploitation. As per the survey made during 1992, out of the total estimated groundwater potential of 2.64 m.ha.m, 2.24 m.ha.m, (85%) were available for irrigation and out of this, only 0.88 m.ha.m, (39.1%) remains to be utilized.

Demand-Supply gap

The increasing demand for water over supply results in a supply-demand gap for water. The worked out supply-demand gap, based on the growth rates of irrigated crops, is 2.12 m.ha.m, (44.72 %). The gap based on National Commission on Agriculture's estimate of 0.48 m.ha.m, (10.12 %). It is important to bridge the supply-demand gap either by reducing the demand or by increasing the supply level to match the growing demand in future.

Bridging demand-Supply Gap

The main concern of productive agriculture is the effective and efficient supply of water to crop fields since irrigation potential is created at huge cost. The investments required for developing surface irrigation for one hectare is estimated at over Rs.50000/-. The overall efficiency under this system is only 30-50%. As more and more areas have to be brought under irrigation, it has become necessary to introduce modern irrigation techniques like microirrigation (drip/microsprinkler), sprinkler etc. for economizing the water use. The efficiency under drip irrigation has been estimated to be as high as 80-90%.

Status of Micro-irrigation

Drip and sprinkler irrigation is followed in many developed countries. Globally, the drip irrigated area is about 2.80 m.ha, representing 1% of the World's total irrigated area. In India, the area coverage under micro irrigation is 3,12,453 hectares only (1.6%) of the total irrigated area. Among the States, Maharashtra is the leading state under micro irrigation followed by Karnataka and Tamil Nadu.

Water is a major component for sustainable development of fruit crops and an indispensable resource which needs careful monitoring and management in order to achieve higher water use efficiencies. The irrigated area under horticultural crops in India is likely to increase from 6.0 to 8.1 m.ha (Srinivas, 1998). In order to utilize the available water efficiently for fruit crops, scientific management of water resources become inevitable. Horticultural crops demand assured irrigation for higher yields. However, these crops provide a conducive situation for the application of drip irrigation and fertigation. The Government has initiated programmes, as a result of which, substantial area has been covered under drip irrigation in the horticulture sector. The growth has been significant in the states of Maharashtra, Andhra Pradesh, Karnataka and Tamil Nadu.

Micro irrigation is suitable for all row crops and especially for wide-spaced high- value crops. The required quantity of water is provided to each plant at

Table 1.Area (ha) covered by fruit crops under drip irrigation in India (State-wise)

Sl.No	Crop / State	Maharashtra	Andhra Pradesh	Karnataka	Tamil Nadu	Other States	Total
1	Banana	31,780	330	3,200	182	145	35,637
2	Ber	3,850	180	380	5	755	5,170
3	Citrus	15,800	5,600	630	1,220	1,450	24,700
4	Grapes	26,800	1,400	4,000	330	20	32,550
5	Guava	1,500	2,100	560	1,520	620	6,300
6	Mango	5,600	12,900	4,300	5,300	1,343	29,443
7	Papaya	1,630	670	440	65	220	3,025
8	Pomegranate	14,100	630	3,900	510	380	19,520
9	Sapota	3,100	630	1,200	575	1,005	6,510

(Sivanappan, 2002)

the root zone through a pipe net work. Hence, there is little loss of water from the soil surface. Micro irrigation is well adapted for undulating terrain, shallow soils, porous soils and water scarce areas. Saline/brackish water can also be used since water is applied daily, which keeps the moisture and salt stress at a minimum.

Micro irrigation, which includes drip and micro sprinklers, is an effective tool for conserving water resources and studies have revealed significant water saving, ranging between 40 and 70% by drip irrigation compared with surface irrigation, and increases as high as 100% in some crops in specific locations (Table.2). Micro irrigation is very popular in wide-spaced horticultural crops like coconut, mango, guava, sapota, pomegranate, lime, oranges, grapes, banana, tapioca, turmeric and close-spaced crops like vegetables, potato and flowers like jasmine, rose etc.

Table.2. Water used and yield of crops in micro irrigation and conventional methods

Crop	Methods of irrigation	Water require-ment (cm)	% water saving	Yield (kg ha^{-1})	% increase in yield	Water use efficiency (kg ha mm^{-1})
Banana	Drip	97.00	45.00	87,500	52.00	90.20
	Surface	176.00	-	57,500	-	32.67
Grapes	Drip	27.80	48.00	32,500	23.00	116.90
	Surface	53.20	-	26,400	-	49.62
Papaya	Drip	73.88	67.89	23,490	69.47	0.32
	Surface	225.80	-	13,860	-	0.06

(WTC Annual Reports 1985-2003)

Fertigation

An approach for efficient utilization of water and fertilizers is necessary for agriculture in the 21st Century. Fertilizers applied under traditional methods of irrigation are not efficiently utilised by the crops. As an alternative, fertigation is gaining popularity all over the world. It was first started in the late 1960's in Israel with the development of drip irrigation and over 75% of the irrigated area is fertilized by fertigation. Since then, fertigation has become very popular in many other countries.

Once investment on drip irrigation is made, it is very easy to achieve the full benefits through the next ultimate step called as ‘Fertigation’. Fertigation is a coined term which means to irrigate and give fertilizers along with it. In other words, fertigation is addition of fertilizers to irrigation water and application via drip or similar micro irrigation system.

Fertigation provides Nitrogen, Phosphorous and Potassium as well as the essential trace elements (Mg, Fe, Zn, Cu, Mo and Mn) directly to the active root zone, thus minimising the loss of expensive nutrients which ultimately helps in improving productivity and quality of farm produce.

Table 3. Fertilizer use efficiencies by various application methods

Nutrient	Fertilizer use efficiency (%)	
	Soil application	Fertigation
Nitrogen	30-50	95
Phosphorous	20	45
Potassium	50	80

(Satisha,1997)

Fertilizers for fertigation

Water in which fertilizers are to be dissolved should have pH levels between 5.8 and 7.8. The solubility of some common fertilizers used in drip irrigation are presented in Table.4.

Table 4. Fertilizers commonly administered in fertigation

Name	Chemical form	N - P_2O_5 - K_2O content	Solubility (g/l) at 20°C
Ammonium nitrate	NH_4NO_3	34	1830
Ammonium sulphate	$(NH_4)_2SO_4$	21	760
Urea	$CO(NH_2)_2$	46	1100
Monoammonium phosphate	$NH_4H_2PO_4$	12	282
Diammonium phosphate	$(NH_4)_2HP_2O_5$	18	575
Potassium chloride	KCl	0	347
Potassium nitrate	KNO_3	13	316
Potassium sulphate	K_2SO_4	0	110
Monopotassium phosphate	KH_2PO_4	0	230
Phosphoric acid	H_3PO_4	0	457

(Bar-Yosef, 1999)

Most of the speciality water soluble fertilizers are imported in India and marketed by Irrigation system and Fertilizer Dealers.

The research evidence showed that drip fertigation in banana (Nendran) with water soluble fertilizers at 125% NPK (T_1) has registered the highest fruit yield of 42.65 t/ha which was 66.76% increase over surface irrigation and soil application of Normal fertilizers (T_5, Table5). Fertigation at 75% dose also registered higher fruit yield of 35.075 t/ha when compared to control (T_5, 25.575 t/ha).

Table 5. Drip fertigation with speciality water soluble fertilizers in Banana (Nendran)

S.No	Treatments	Yield (t/ha)	% water saving	Marginal B:C ratio	Net income (Rs./ha)
T_1	Drip fertigation with WSF at 125 % NPK	42.650	47.57	6.80	1,34,768
T_2	Drip fertigation with WSF at 100% NPK	37.450	47.57	6.70	1,17,804
T_3	Drip fertigation with WSF at 75 % NPK	35.075	47.57	7.79	1,14,991
T_4	Drip irrigation + soil application of NF at 100% NPK	30.325	47.57	6.50	94,741
T_5	Surface irrigation + soil application of NF at 100% NPK	25.575	-	-	80,791

(Asokaraja, 2002)

Economics of micro irrigation and fertigation

The cost for installing drip irrigation varies from Rs.20,000 to 25,000/ha for wide spaced crops like coconut, mango etc. The cost of the system depends upon the crop, spacing, quantity of water required, distance from water source etc. The economics of micro irrigation has been calculated with and without fertigation and presented in Table.6 It is observed that for most of the crops, benefit cost ratio varies from 2 to 5.

Table 6. Cost of micro irrigation with and without fertigation system for fruit crops

Crops	Spacing (m)	System type	System Cost (Rs./ha)	
			Without fertigation	With fertigation
Mango	10 x 10	Dripper	17784	21517
Citrus	6.0 x 6.0	Dripper	25012	28745
Sapota	9.0 x 9.0	Dripper	18998	22731
Pomegranate	4.5 x 2.7	Dripper	27952	31685
Grapes	2.7 x 1.8	Dripper	46769	50502
Papaya	1.8 x 1.8	Dripper	45000	48500
Banana	1.8 x 1.8	Dripper	45000	48733

(WTC Annual Report, 2003)

Constraints of micro-irrigation

1. Clogging

Emitter clogging continues to be the major problem associated with drip irrigation system. It disrupts the operation of system and reduces the uniformity of application. Since a drip irrigation system is expensive, longevity must be maximized to assure a favourable B:C ratio. Emitter clogging is directly related to the quality of the irrigation water i.e., suspended load, chemical composition and microbial activity. Consequently, these factors dictate the type of water treatment necessary for the prevention of clogging. As the water flows at a low rate, the small opening gets easily filled up with algal, dust or salts in irrigation water, thus causing clogging of the emitters. Mainly, the clogging is due to organic materials found in water or precipitated carbonates of calcium and magnesium salts in the irrigation water.

Quality of irrigation water

The water analysis data listed in Table 7 can be classified into physical, chemical and biological factors that play major role in the clogging process. Lesser the quantities of solids, salts and bacteria in water, lesser are the clogging hazard.

Table 7. Tentative water quality criteria for indicating emitter clogging hazards

Type of problem	Minor	Moderate	Severe
Physical Suspended solids [a]	50	50 - 100	**>100**
Chemical			
H	7.0	7.0 - 8.0	>8.0
Dissolved solids [a]	500	500 - 2000	>2000
Manganese	0.1	0.1 - 1.5	>1.5
Total iron	0.2	0.2 - 1.5	>1.5
Hydrogen sulphide [a]	0.2	0.2 - 2.0	>2.0
Biological Bacterial population [b]	10,000	10,000 - 50,000	>50,000

a. Maximum measured concentration (mg /1) in irrigation water (Bucks and Nakayama, 1980)
b. Maximum number of bacteria per ml of water

To find the causes, extend and remedial measures to reclaim the clogged emitters, a study was undertaken at TNAU, Coimbatore in the drip irrigated fields. Among the three drippers of the same pressure and temperature, the discharge rate and the standard deviation observed are given in Table 8.

Table.8. Discharge variation in the different

Emitters	Average discharge l/h	Std. Deviation (observed) %	Remarks
Hole and socket type(1 mm dia) 5 l/h	3.40	5.0	Pressure and temperature kept constant
Micro tube (1mm) 4 l/h	2.50	5.0	
Nozzle 10 l/h	8.50	6.5	

(Padmakumari and Sivanappan, 1985)

It was seen that the standard deviation of the change in discharge rate in a fortnight was 5% for all the holes and socket as well as micro tubes and 6% for the nozzles. The extent of reclamation of partially clogged emitters treated with HCl had resulted in an increase of 0.2 l/h where the acid concentration increased from 0.5 to 2.0% volume. But, it was found to be not much suitable to reclaim orifices fully blocked. The acid-water mixture at higher pressure was found useful including the drippers. Among the chemicals, sodium hypo chlorite was found to be the most effective in improving the discharge rate.

Clogging Control

a. Filtration

The selection of filtration system for irrigation depends upon the type of water source and quality of water. Generally surface water pumped from open water bodies like ponds, lakes, rivers, streams, canals and wells contain more impurities than underground water. Hence the water has to be filtered before approaching to the emitters. The filtering media may be different type like screen, gravel or sand and disc filter (Taley, 1999).

Strategies for of filtration

- Ensure that screens and seams of the filter are not damaged.
- Ensure proper tightness in the filter assembly
- When pressure differential reaches approximately 0.5 kg/cm^2, system should be flushed and cleaned.
- Avoid entry of dirt into the pipe when the filter is opened for cleaning
- Automatic back-flushing may be appropriate

Filtration does not prevent the penetration of very small, suspended particles and water-soluble matter. The end of the laterals experiences the greatest accumulation of sediment.

b. Chlorination

Chlorine is an oxidizing agent, which kills bacteria, algae and other organic matter. The most common chlorine compounds are sodium hypo chlorite (liquid) and Calcium hypo chlorite (solid). Sodium hypo chlorite (as 10% chlorine) which has been used as a dairy sanitizer, is relatively safe and easier to use (Asokaraja and Palanisami, 2001).

Continuous chlorination

Continuous treatment of the irrigation water is probably the best and in the long run, the simplest method of avoiding blockage problems in drip irrigation. The aim is to treat the water all the time to keep the system (filters, laterals and drippers) clean from organic matter.

The required concentration will vary according to the water quality. By trial and error, the injection rate must be adjusted so that 1 ppm of chlorine is detectable at the end of the lateral. The common concentration to begin with is 5-10 ppm (mg/l). A chlorine test kit (eg. swimming pool test kit) may be used to detect the presence of chlorine.

Example:-Suppose pump discharge is 20 cu.m/hr, Irrigation time is 3 hr, Rate of chlorine required is 5 ppm (mg/l), 1 ppm = 1g/cu.m (1000 liters), 5 ppm=500 g chlorine/hr = 5000 g as 10% hypo chlorite/hr, therefore total hypo chlorite required = 3 hr x 5000g = 15 kg.

The normal concentration (for intermittent chlorination) for improving the filtering systems ranges between a level of 2 to 5 ppm of free chlorine remnant.

The calculation of the rate of chlorine injection will be made as follows

$$\text{Supply of chlorine solution} = \frac{\text{Water flow of the system m}^3\text{/h} \times \text{Desired chlorine conc.ppm}}{\text{Chlorine concentration in the solution (per cent)} \times 10}$$

Example- Water flow of the system is 20m3/hr, concentration of sodium hypo chlorite solution is 10%. Dilution ratio in storage container is 1:1, desired concentration of pure chlorine is 5 ppm.

$$\text{Then, the chlorine to be injected (lph)} = \frac{20 \times 5}{10 \times 5} = 2 \text{ lph}$$

According to the above data, 2 liters of solution will be injected per hour.

c. Acidification

Precipitated Calcium salts appear as a white film or plating on the inner surface of the drip system. With some water, precipitated calcium salts will eventually block the drip emitters. Injection of 30% hydrochloric acid (HCL) or other acids of similar concentration is an easy solution (Asokaraja and Palanisami, 2001).

Procedure

- Flush all sub mains and laterals. It is recommended to divide the irrigated area into small plots and treat each plot individually

- Check the discharge of the system before treatment to compare with treated system
- Dose required - 1 litre per cu.m discharge of the irrigation system
- Injection method- Use only pumps that are acid resistant (eg. Fertilizer injection pump)
- Test the maximum discharge of the injector pump
- Prepare a solution equal to one tenth of the maximum discharge of the injector pump
- Injector should be started with the irrigation system operating
- Check the pH at the farthest lateral with a pH test kit or litmus paper. The required pH is 4.0
- Continue irrigation for 30-60 minutes.

Example: Pump discharge:20 cu.m/hr, Max. injector pump discharge: 250 lit/hr, Acid required: 20 litres (1 litre per cu.m), Total solution required : 250/10 =25 litres (1/10th of the discharge), water quantity to use: 25-20 = 5 litres, if discharge is higher, use only acid.

Conclusion

Micro irrigation is very well suited for fruit crops but it has not been fully exploited. In India, the area of irrigation of fruit crops is only about 30% and the average productivity is very low. The fruit production currently is not sufficient, to the prescribed per capita, though there is tremendous scope in extending the area of irrigation for fruit crops.

Fertigation is a sophisticated and efficient method of applying fertilizers, in which the irrigation system is used as the carrier and distributor of the crop nutrients. The synergism and combination of water and nutrient leads to an efficient use of both by the plant. Based on the studies conducted on different horticultural crops, it was found that adoption of this technology improves the yield and the quality of crops. It is also highly beneficial to farming community to reduce the cost of production.

Poor maintenance of Micro-irrigation systems and especially drip irrigation, leads to chocking of emitter points. Hence, functioning of drip system is not up to the expectations and some time, resulted in failure of the irrigation network. This throws away the spirit and confidence of the farmers using drip system. Emitter clogging is due to improper maintenance of filtration system and absence of periodical flushing. Periodical flushing helps in minimizing the sediment build-up in the lines. After each fertilization treatment, it is essential to flush the laterals. The inspection of drip system for uniformity of water application at frequent intervals helps to manage the drip-irrigated farm without any problem. This paper has attempted to show that if the water is sampled, analyzed, appropriate filtration systems are installed and chemical water treatment programs are initiated, then, there should be no major problem with clogged emitters.

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1ea(Nutrie t Norms - DR1S Approaches i 7ruit Crops

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Leaf is the principal site of plant metabolism; therefore, changes in nutrient supply are reflected in the composition of the leaf / petiole. These changes are more pronounced at certain stages of development and the leaf nutrient concentration at specific growth stages are related to crop performance. Soil test, particularly in perennial fruit trees and grapevines has not been found very useful in making nutrient recommendation due to their specific root distribution and low plant density.

Leaf analysis as a guide to fertilization is based on the premise that "crop behaviour is related to concentrations of essential minerals in the index tissue. Environmental and procedural factors vitiate the leaf nutrient concentration in large number of fruit crops. However, a carefully worked out sampling technique for index tissue will make a sound foundation of leaf analysis data such as "Diagnosis and Recommendation Integrated System" and "Boundary Line Approach" can be adopted to diagnose the growth / yield limiting nutrient and to recommend optimum use of fertilizers. Physiological basis of leaf sampling at bud initiation and differentiation stage seems to hold the key to meaningful relationship of plant nutrient status with potential yield according to "Physiological stage concept".

Leaf Analysis

Leaf Analysis is based on the premise that plant behavior is related to the concentrations of essential minerals in leaf tissue. Leaf analysis as a method for assessing the nutrient requirements of a given crop is based on the assumption that, within certain limits, there is a positive relation between dose of the nutrient supplied, leaf content and yield .The leaf analysis can be useful in one of the following ways

1. To develop a nutrient guide for recommendation of manures and fertilizers for economic optimum yield.
2. To correct defective manure and fertilizer application used by the growers which often lead to soil, water and environmental problems
3. To determine whether or not the supply of one or more nutrients is inadequate, satisfactory or unnecessarily high.
4. To provide a common denominator for making parallel comparison from solution, sand, soil and field cultures, location, year and climate.
5. To show that the lack of response to applied nutrients result from their failure to make into the leaves, thereby preventing a wrong conclusion from being drawn and directing attention to the cause of the lack of absorption.

Steps in Leaf analyses

1. Leaf sampling techinque: The general principle in leaf sampling is to collect 'Recently / Youngest mature leaf or petiole' (Ulrich, 1948). Depending on rates of growth, the age of recently mature leaves varies (Table .1). The nutrient concentration in the index tissue is influenced by factors associated with the plant or with environment and soil or those related to sample handling and processing.

2. Sample Handling**:** The general to be followed in sample handling are: 1. Field sampling should be carried out early in the morning. Scientist carrying out sampling should wash hands before sampling or use dispensable gloves. The collected material should be immediately shifted to cool containers.. After transport from the field the samples can be stored in refrigerator at 5°C till these are decontaminated. Samples covered with soil particles may be cleaned using deionized water. For micronutrient determinations, avoid contact between the plant material and metals. If it is difficult to send the samples to the laboratory within 12 hours,

these may be washed at the sampling site and partially dried before mailing to the laboratory.

3. Decontamination: Fresh samples on receipt must may be divided into 4 sub-samples for effective washing in minimum time. One sub-sample may be pre-washed with deionized water, if it is soiled. If sprayed chemical deposits are visible, the deposits can be removed by cotton soaked in 0.2 % detergent solution. The sample should be passed through four solutions. viz. 0.2% detergent solution, N/10 HCl solution, distilled water and finally in deionized water or double distilled water. Samples for boron estimation should be washed in distilled water from stainless steel.

4. Sample Drying

a. Initial drying**:** is designed to de-activate rapidly all plant enzymes thereby minimizing weight loss and biochemical changes, and to remove all water from the tissues so that the sample reaches an oven dry state when its weight remains unchanged with repeated drying. The samples may be dried at 65°C to 70°C in stainless steel lined hot air ovens which allow adequate circulation of air between samples.

b. Final drying**:** Initially dried samples are sometimes weighed, ground and stored for a period to the analysis when these may absorb atmospheric moisture. This necessitates second drying at 70°C for 12 hours immediately before analysis.

5. Grinding and Storage**:** Dried samples are ground to reduce field samples to manageable size and facilitate the preparation of homogeneous sub-samples for chemical analysis. During grinding, care must be taken to ensure that it does not segregate into labeled, air-tight glass or poly-carbonate containers which can withstand a second drying cycle. This should prevent samples from being infected by insects during storage.

6. Laboratory Analysis: Standard and reproducible techniques should be used. With the advent of computer linked report generating instruments improvements in the efficiency and speed of quantitative plant analysis have become possible.

Leaf nutrient level categories: For an ideal leaf nutrient guide, 5 range for each element can be used for classification of the nutritional status of fruit trees, namely, deficient, low, optimum high and excessive / toxic based on yield and fruit quality responds.

Leaf Nutrient guide: The leaf nutrient guide must be calibrated through long term well designed experiments under normal field conditions and these may take as long as 20 to 25 years to obtain reliable results. For this reason, there are still fewer leaf analysis guides available than are necessary to establish accurate norms.

Interpretation of Leaf Analysis Data: Leaf analysis has been interpreted in several ways and new concepts are

Table 1. Index tissue sampling technique in fruit crops for yield

Crop	Index tissue	Stage	Particulars	Sample size
Grape(Vitis vinifera L)	Petiole	Bud differentiation	5th petiole from base for yield forecast	200
	Petiole	Bloom	Petiole opposite to bloom for quality.	200
Banana AAA group (Musa cavendish sub-group)	Petiole or Midrib	Bud differentiation	Petiole of 3rd open leaf from apex	15
Ber(Zizyphus maurotoama Lamk.)	Leaf	2 months after pruning	6th leaf from apex from secondary or tertiary shoots	40
Acid Lime(Citrus aurnatifolia	Leaf	June	3 to 5 month old leaf from new flush.	30
Custard apple (Anona squamosa L)	Leaf	2 months after new growth	5th leaf from apex	30
Papaya(Carica papaya L)	Petiole	6 months after planting	6th petiole from apex.	20
Pomegranate (Punica granatum Linn)	Leaf	Bud differentiation stage	8th leaf from apex.	50

Table 2. Leaf Nutrient Guide for Mango - Dashehari

Nutrient	Unit	Critical limit
Nitrogen	%	1.23
Phosphorus	%	0.06
Potassium	%	0.54
Calcium	%	1.71
Magnesium	%	0.91
Sulphur	%	0.12
Iron	Ppm	171
Manganese	Ppm	66
Zinc	Ppm	25
Copper	Ppm	12
Leaf of 5-6 month age from center of shoot Samra and Thakur (1978)		

Table 3. Leaf Nutrient Guide for Guava (*Psidium guajava* L.)

Nutrient	Status		
	1	2	3
Nitrogen	1.63 - 1.96	-	-
Phosphorus	0.18 - 0.24	-	0.45 - 0.65
Potassium	1.31 - 1.71	1.25 - 1.47	-
Calcium	0.67 - 0.83	-	-
Magnesium	0.52 - 0.65	-	-
1. Khandhuja's and Garg (1980) - Confidence limits 2. Singh and Rajput (1976) - Regression 3. Rajput and Singh (1976) - Regression			

Table 4. Petiole / Lead Nutrient Guide fof Banana for Yield and Quality

Nutrient	Leaf Part	Potassium (%)
Nitrogen	Petiole	0.98
	Midrib	0.80
	Lamina	2.57
Potassium	Petiole	5.34
	Midrib	3.64
	Lamina	4.12

Table 5. Critical Limits of N and P for Pineapple

Nutrient	Leaf part	Age (Month)	Kew Pineapple	Queen Pineapple
Nitrogen	Leaf base	5	1.51	-
		8	1.23	-
		11	1.97	1.04
	Leaf lamina	5	0.99	-
		8	0.81	-
		11	1.37	-
Phosphorus	Leaf base	11	-	0.165
	Leaf lamina	11	-	0.206
1. Rao et al. (1997) 2. Subramanian et al. (1978)				

Table 6. Nutrient Guide for Banana – Robusta (*Musa* spp. group Cavandish subgroup Robusta)

Index Tissue	Unit	20th leaf stage	20th	32nd leaf stage
		N		K
Leaf lamina Petiole	% %	2.57 0.95	5.90 5.60	5.60 4.60
Midrib	%	0.76		

being evolved at various stages of development for use in fruit nutrition. Six such concepts are as follows.

1. Critical nutrient concept: This technique has been used by Subramanian *et al.* (1974), Samra and Thakur (1978) and Chadha *et al.* (1980) to divide orchards expected to give a relatively large response to a particular fertilizer nutrient, from these expected to give little or no response assuming that other nutrients are present in adequate amounts.

A dividing line between two categories (high and low probability or response) might be determined approximately by a graphical technique in which vertical and horizontal lines are super imposed on a scatter diagrams so as to maximize the number of points in the positive quadrants. The horizontal line is 90 percent probability line and the vertical line is so drawn that maximum points of the scatter diagram are on two positive quadrants. The vertical line which is determined by eye judgment is known as the critical level (Tables 2, 3, 4, 5 and 6).

2. Yield groups and Nutrient content: Samra *et al.* (1978) adopted grouping of yield levels in mango e.g. < 150, 150-300 and <300 fruits / tree to work out the leaf nutrient standards (Table # 8).

There were variations between the critical limits reported for young trees in sand culture and those actually observed in fully grown trees in orchards. In sand culture, nutrients are available freely leading to their uptake in excessive amounts, whereas in orchard soil, the nutrients are generally bound to the exchange complex with varying degrees of affinity and hence their effective concentration are very low.

3. Nutrient concentration range: It is well established that there is generally a good relationship between

Table7. Nutrient of Macro-Nutrients in High, Medium and Low Yielding Trees of Coorg Mandarin

Nutrient	Yield level (Fruits / tree)			
	High(> 1000)	Medium (500 to 1000)	Low (< 500)	CD 5 %
Nitrogen (%) South Coorg North Coorg	2.88 2.90	2.77 2.79	2.70 2.63	0.05 0.16
Phosphorus (mg%) South Coorg North Coorg	146150	**144157**	**139155**	**NSNS**
Potassium (%) South Coorg North Coorg	1.63 1.63	1.48 1.56	1.36 1.50	0.13 0.10
Calcium South Coorg North Coorg	1.27 2.08	**1.49** **2.41**	**1.80** **2.25**	**0.24** **NS**
Magnesium South Coorg North Coorg	320 363	357 381	390 443	2 NS

concentration of a nutrients and growth and yield. (NR is defined as the range of nutrient at a specified growth stage above the upper limit of which we are reasonably confident that the crop is amply support and below the lower limit of which are reasonably confident that the crop deficient.

4. Nutrient Balance: Factorial method: A system based on Liebig's is Law of minimum has been developed

Table 8. Critical Limits of Leaf Nutrients for Mango

Nutrient	Unit	Samra *et al.* (1978)		Kumar and Nauriyal (1969)		
		Range	Mean	1	2	3
Nitrogen	%	0.95 - 1.45	1.22	1.88	0.98	0.68
Phosphorus	%	0.03 - 0.12	0.05	0.15	0.08	0.03
Potassium	%	0.40 - 0.77	0.53	0.95	0.50	0.24
Calcium	%	1.74 - 3.45	2.58	2.44	1.53	0.81
Magnesium	%	0.22 - 0.75	0.44	0.32	0.16	0.10
Sulphur	%	0.06 - 0.22	0.29	0.74	0.52	0.32

1. Complete nutrient solution
2. Deficient solution
3. Severely deficient solution

Table 9. Leaf Nutrient Guide for Coorg Mandarin (*Citrus reiculata*)

Nutrient	Unit	Vegetative shoots	Floral shoots
Nitrogen	%	2.08 - 2.79	1.85 - 2.48
Phosphorus	%	0.09 - 0.18	0.09 - 0.15
Potassium	%	0.78 - 2.08	0.76 - 1.89
Calcium	%	2.88 - 4.60	3.18 - 5.25
Magnesium	%	0.25 - 0.47	0.28 - 0.51
Iron	ppm	103 - 160	77 - 165
Manganese	ppm	54 - 220	50 - 124
Zinc	ppm	31 - 82	31 - 84

Table 10. Micronutrient Ranges in Pineapple

Nutrient	Unit	Range
Iron	ppm	128 - 336
Manganese	ppm	254 - 300
Zinc	ppm	9.8 - 35.1
Copper	ppm	5.9 - 12.4

Table 11. Leaf Nutrient Guide for Ber (*Zizyphus mauritiana LamK*).

Nutrient	Unit	Confidence Limit
Nitrogen	%	2.77 - 3.32
Phosphorus	%	0.18 - 0.32
Potassium	%	1.69 - 1.96
Calcium	%	1.07 - 1.36

Table 12. Leaf Nutrient Guide for Passion Fruit CV Purple (*Passiflora edulis* Sims)

Nutrient	Unit	Status
Nitrogen	%	4.07
Phosphorus	%	0.18
Potassium	%	0.96
Calcium	%	1.79
Magnesium	%	0.63
Iron	%	102
Manganese	%	370
Zinc	%	60

Sample Opposite to Opening Floral Bud, Rao *et al*., (1988)

which takes nutrient balance, synergisms and antagonisms into account using factorial experiments, the effect of increasing levels of one of several factors is calibrated keeping all other conditions constant. From these calibrations, it was possible to determine the relative proportions of nutrient for balanced nutrition. The major problem with this approach may be interactions between the factors being varied and those kept constant.

5. Balance index: Balance index has been used by Awasthi *et al*. (1979) to workout judicious nutrient doses for apple in Himachal Pradesh. The concept of nutrient balance is sometimes difficult to understand unless the composition values are converted to percent of standard values. Therefore, a means of adjusting the percent of standard values is needed to account for normal variation. This can be done by use of coefficient of variations for normal plants to develop a balance index.

The Kenworthy's balance index is calculated by the following procedure:

i) If a sample value (X) is smaller than standard value (S), then balance Index is calculated by

$$P = (X / S) x 100$$

$$I = (100 - P) x V / 100$$

$$B = (P + I)$$

Where B is balance Index. I is influence of variation. P is per cent of standard. V is coefficient of variation. S is standard value and X is value of sample under diagnosis.

ii) If sample value (X) is larger than the standard value (S), then calculation will be

$$P = (X / S) X 100$$

$$I = (P - 100) X (V / 100)$$

$$B = (P - I)$$

These calculations tend to move per cent value calculations towards a balance index of 100 based on the co-efficient of variation for each nutrient.

6 Diagnosis and Recommendation Integrated System (DRIS):

DRIS represents a holistic approach to the mineral nutrition of crops and has impact on integrated set of norms representing calibrations of plant tissue and soil composition, environmental parameters and farming practices as functions of yield of a crop. Once such norms have been derived, it is possible to make a diagnosis of the condition of the crop thereby isolating the factors which are likely to be limiting growth and production. The most important advantages of DRIS approach and its ability to make a diagnoses at any stage of crop development and to list the nutrient elements in the order of importance in limiting yield. DRIS has been developed to fulfill the predictive use of leaf analysis. Optimizing these factors creates condition which is likely to increase the chances of obtaining higher yield and quality.

Development of DRIS Norms: It contrast to the classical field experiment approach to leaf analysis, the DRIS employs survey technique where a large number of randomly distributed sites throughout the area are selected. At each site, samples of leaf and soil are taken for analysis and the details of applied manures and fertilizers are recorded. Experiment conducted at one place employing various levels of 1, 2 or 3 plant nutrients can also be used to develop DRIS taking the following steps:

1. Define the parameters to be improved and the factors likely to affect them.
2. Collect all reliable data available from field and experimental plots.
3. Study the relationship between yield and environmental or external factors such as soil composition, weather conditions, etc. so that the most favorable condition can be determined in a particular case. This will help taking suitable corrective measures on such inter-relationships.
4. Study the relationship between yield and internal parameters such as petiole composition using following steps.

a) Each internal plant parameter is expressed in as many forms as possible, e.g. N / DM, DM / N, N / P, P / N, NXP, etc.

b) The whole population is divided into a number of some groups based on yield into two groups of high and low yield.

c) The means of each sub-population are calculated for various forms of expression.

d) If necessary, class interval limits between average and outstanding yields are readjusted to so that means of below average and average yielding population remain comparable.

e) Chi-square test is used to know that sub-population confirm to a normal distribution.

f) The variance ratios between yield of sub-populations for all forms of expressions are calculated together with the co-efficient of variation.

g) The forms of expressions, for which significant variance ratios are obtained and the mean values for the population are essentially the same, are selected and related to one another in expression with common nutrient.

h) For calculating DRIS index, Bhargava (1987) used the following formula for petiole N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu and yield of grapes. The formulae are :

where f (N / p =	**N / P** **..................... 1** **n / p**	**1000** **.......................** **CV**	**when N / P > n / p**
and f (N / p =	n / p 1.................. N / P	1000 CV	when N / P < n / p

in which N / P is the actual value of the ratio of nitrogen and phosphorus in the plant under diagnosis. The n / p is the value of the norm (which is the mean value of high yielding orchards) and C.V is the co-efficient of variation for population of high yielding orchards.

P = 1 / 10 [(-f(N/P)+f(P/K)-f (Ca/P)+(P/Mg)-f(S/P)-f(Fe/P)+f(P/Mn)+f(P/Z)

$K = 1/10 [f(K/N)-f(P/K)-f(Ca/K)-f(Mg/K)-f(S/K)-f(Fe/K)+f(K/Mn)+f(K/Z)$

$Ca = 1/10 [(-f(N/Ca)+f(Ca/P)+f(Ca/K)+f(Ca/Mg)+f(Ca/S)-f(Fe/Ca)+f(Ca/M)$

$Mg = 1/10 [-f(N/Mg)-f(P/Mg)+f(Mg/K)-f(Ca/Mg)-f(S/Mg)-f(Fe/Mg)+f(Mg/Mn)+$

$S = 1/10 [(-f(N/S)+f(S/P)+f(S/K)+f(Ca/S)+f(S/Mg)-f(Fe/S)+f(S/Mn)-f(Z)$

$Fe = 1/10 [(f(Fe/N)+f(Fe/P)+f(Fe/K)+f(Fe/Ca)+f(Fe+Mg)+f(Fe/S)-f(Mn/Fe)-$

$Mn = 1/10 [(-f(N/Mn)-f(P/Mn)-f(K/Mn)-f(Ca/Mn)-f(Mg/Mn)-f(S/Mn)+f(Mn/P)$

$Zn = 1/10 [(-f(N/Zn)-f(P/Zn)-f(K/Zn)-f(Ca/Zn)-f(Mg/Zn)+f(Zn/S)+f(Zn/P)$

$Cu = 1/10 [(f(Cu/N)+f(Cu/P)+f(Cu/K)+f(Cu/Ca)+f(Cu/Mg)+f(Cu/S)+f(Cu/Fe)+$

$Y = 1/10 [(-f(N/Y)-f(P/Y)-f(K/Y)-f(Ca/Y)-f(Mg/Y)-f(S/Y)-f(Fe/Y)-f(Mn/Y)$

Initially standard values or norms were determined from DRIS. These standard values were then used to develop indices by following the equations given above. The value of each ratio function is added to one index sub-total and subtracted from another prior to averaging. Therefore, all indices are balanced around zero. The higher negative index shows that the corresponding nutrient is relatively deficient. Alternatively, a large positive index indicates the nutrient is excessive in quantity.

The norms for classification of nutrients in plants were derived by following the procedure given below.

The mean of high yielding orchards constituted the mean for optimum. The range of 'optimum' is the value derived from mean -4/3 (Standard deviation) SD to mean + 4/3 SD. The range of 'low' was obtained by calculating mean - 4/3 SD to mean -8/3 SD, and the value below mean -8/3 SD was considered as deficient. The value from mean +4/3 SD to mean +8/3 SD was taken as high and the value above mean +8/3 SD was taken as excessive or toxic (Bhargava, 1995).

Diagnosis: DRIS is a holistic system of nutrient diagnosis and can be used for isolating nutrients and other factors which determine yield level and the quality of produce. The system is capable of making diagnosis of index tissue with variable ages, identifying deficiency or toxicity of nutrient. This predicts the probable sub-optimal status of a nutrient and list the nutrients an order of their limiting importance on yield, so that correction of deficiency can be made.

DRIS has advantage over other methods as it allow index tissue sampling for a wider period of time since the diagnosis is based on large number of nutrients and can also reveal hidden hunger. The degree of reliability of DRIS can be evaluated by comparing the nutrient diagnosis using leaf analysis data and soil fertility parameter. In most cases, the diagnosis is the same. Some examples of diagnosis are given below:

Recommendations: Based on the diagnosis made recommendations will be proposed. Some examples are given here based on the diagnosis made in grapes, mango, banana and acid lime (See table 13)

Grapes**:** The data above clearly showed that the deficiency of Zn, Mg and excess of Fe, N affect the yield of grapes as shown by -ive and +ive values against DRIS indices for these nutrients. If the first liming factor Zn is corrected by its supply, the next nutrient which will limit the yield will be Mg. Further, application of primary nutrients by fertilizers will not fully express its influence on yield and quality due to deficiency of secondary and micro-nutrients.

Mango**:** The low yield of mango is due to acute deficiency of Zn, followed by Mg when these two nutrients are applied the next nutrient which may restrict yield would be S and N.

Banana**:** Banana is grown in Alfisols of southern Karnataka by applying the recommended dose of primary nutrients i.e., 200 g N, 300 g K_2O / plant in 4 splits along with 50 g P_2O_5 as based. However, full yield is not obtained unless Mg, Zn and B are applied at the rate of 25 to 50 g magnesium sulphate, 10 to 20 g zinc sulphate and 2.5 to 3.0 g borax / plant through soil. Boron can also be applied as foliar spray at the rate of 1 g / liter with surfactant.

Acid lime: Sulphur is the most deficient nutrient and application of elemental S or through super phosphate (11% S) will supply S. The next nutrient needed to boost yield further would be Mg and then P followed by N.

The diagnosis made on four fruit crops bring out the need for applying secondary and micronutrients along with primary ones. It is necessary to provide a soft base of organic manure which make the plant comfortable for efficient utilization of applied nutrients.

Critical leaf nutrient norms have been published for various fruit crops. For additional reading the reader is referred to Bhargava and Chadha (1993) and Bhargava and Room Singh (2000).

Limitations of Leaf Analysis:

There are some limitations in its use, some of which are attributed to lack of required knowledge to get the full benefit from leaf analysis, others are limitations that are inherent for various reasons and after little or no change of being overcome.

One of the recognized limitations of legal analysis is that it is not a complete diagnostic device. The leaf analysis data do not indicate the doses of plant nutrients required for economically optimum yield. The optimum does of various plant nutrients have to be worked out in separate experiments or growers have to be advised to modify, the existing schedule of fertilization based on analytical data. As a whole it reflects rather poorly the changes in soil reserves, soil acidity, alkalinity or salinity or other factors that affect growth and productivity. Thus, leaf analysis may give little or no information of encroaching root toxicities of such elements as Na, Cl, Se, Pb and Cu. It is only after considerably root damage has been sustained that these elements "leak" through to the leaves. Analysis of rootlets is preferable in such cases. Leaf analysis does not always reflect response in the obvious way.

Table 13. Nutrient Diagnosis using DRIS Indices

Crop	**Limiting Nutrients**					**Nutrients of excess**					
GRAPE											
	DM	Zn	Mg	Mn	Ca	K	S	P	Cu	N	Fe
Nutrient status	**22.24**	**18**	**0.26**	**30**	**1.26**	**1.34**	**0.12**	**0.52**	**14**	**1.07**	**108**
DRIS Indices	-24	-269	-97	-45	-18	5	64	67	147	158	242
MANGO											
	DM	Zn	Mg	S	N	Cu	Fe	Ca	K	Mn	P
Nutrient status	4.60	10	0.11	60	1.00	16	810	1.26	1.42	480	49
DRISIndices	187	-134	-129	-108	-51	-14	-9	23	60	204	344
BANANA											
	DM	K	Mg	N	Zn	P	S	Ca	Cu	Mn	Fe
Nutrient status	15.00	1.50	0.17	1.10	20	110	0.24	1.50	10	200	180
DRISIndices	-285	-260	-180	-35	-10	5	18	47	110	195	205
ACID LIME											
	DM	S	Mg	P	N	K	Cu	Mn	Zn	Ca	Fe
Nutrient status	3.10	0.22	0.22	0.11	1.8	1.33	13	50	19	4.13	489
DRIS Indices	-708	-272	-231	-137	-83	-22	28	65	166	189	1007

Table 14. Leaf Nutrient Norms for Alphonso Mango

Nutrient	Unit	Status			
		Deficient	**Low**	**Optimum**	**High**
N	%	< 0.31	0.32 - 0.77	0.78 - 1.65	1.66 - 2.09
P	mg %	< 16.6	16.6 - 22.3	22.4 - 33.6	33.7 - 39.3
K	%	< 0.27	0.27 - 0.76	0.77 - 1.73	1.74 - 2.22
Ca	%	< 0.31	0.31 - 0.75	0.76 - 1.63	1.64 - 2.07
Mg+	%	< 0.21	0.21 - 0.39	0.40 - 0.65	0.66 - 0.87
S	mg %	< 20	20 - 34	35 - 131	133 - 179
Fe	ppm	< 504	504 - 656	657 - 961	961 - 1114
Mn	ppm	< 10	10 - 13	13 - 408	408 - 605
Zn	ppm	< 2.4	2.4 - 7.7	7.8 - 18.3	18.4 - 23.7
Cu	ppm	< 12.5	12.5 - 14.2	14.3 - 17.8	17.9 - 19
Y	t / ha	< 4.2	4.2 - 5.3	5.4 - 7.4	7.5 - 8.5

* The norms for Mg is based on larger data base obtained on different of mango grown in peninsular India.

Table 15. Leaf Nutrient Guide for Mango CV Totapuri

Nutrient	Unit	Status			
		Deficient	**Low**	**Optimum**	**High**
Nitrogen	%	< 0.47	0.47 - 0.83	0.84 - 1.53	1.54 - 1.88
Phosphorus	mg %	< 26	26 - 63	64 - 147	148 - 186
Potassium	%	< 0.22	0.22 - 0.51	0.52 - 1.10	1.20 - 1.40
Calcium	%	< 1.33	1.33 - 1.96	1.97 - 3.20	3.30 - 3.80
Magnesium	%	< 0.21	0.21 - 0.39	0.40 - 0.65	0.66 - 0.87
Sulphur	mg %	< 112	112 - 146	147 - 215	216 - 249
Iron	ppm	< 28	28 - 47	48 - 86	87 - 105
Manganese	ppm	< 20	20 - 57	57 - 174	175 - 232
Zinc	ppm	< 5	5 - 24	25 - 53	34 - 43
Copper	ppm	< 0.47	0.47 - 3.00	3.10 - 8.00	8.10 - 10.60
Yield	t / ha	< 9.20	9.20 - 10.40	10.50 - 13.70	12.80 - 14.00

Table 16. Petiole Nutrient Norms for Thompson Seedless Grapes - Bud D Stage for Yield Forecast

Nutrients	Unit	Status			
		Deficient	Low	Optimum	High
Nitrogen	g / 100 g	< 0.50	0.51 - 0.86	1.24 0.87 - 1.61	1.62 - 1
Phosphorus	g / 100 g	< 0.11	0.12 - 0.28	0.470.29 - 0.65	0.66 - 0
Potassium	g / 100 g	< 1.49	1.50 - 1.99	2.512.00 - 3.02	3.03 - 3
Calcium	g / 100 g	< 0.79	0.79 - 0.97	1.180.98 - 1.36	1.37 - 1
Magnesium	g / 100 g	< 0.40	0.41 - 0.62	0.870.63 - 1.10	1.11 - 1
Sulphur	g / 100 g	< 0.07	0.07 - 0.08	0.120.09 - 0.13	0.14 - 0
Iron	mg / g	< 40	40 - 53	6754 - 80	81 - 9
Manganese	mg / g	< 10	10 - 40	12542 - 209	210 - 29
Zinc	mg / g	< 10	10 - 25	6730 - 88	89 - 10
Copper	mg / g	< 2	2 - 5	7.55 - 1030.26	100 - 24
Yield	t / ha	< 23.16	23.16 - 26.60	26.71 - 33.82	33.83 - 37.37

Table 17. Petiole Nutrient Guide for Thompson Seedless Grapes - Full Bloom Quality

Nutrients	Unit	Range			
		Deficient	Low	Optimum	High
Nitrogen	g / 100 g	< 0.87	0.87 - 1.31	(1.76)-1.32 - 2.21	2.22 - 2
Phosphorus	g / 100 g	< .19	0.19 - 0.37	(0.57)-0.38 - 0.75	0.76 - 0
Potassium	g / 100 g	< 0.60	0.60 - 1.13	(1.67) -1.14 - 2.20	2.21 - 2
Calcium	g / 100 g	< 0.53	0.53 - 0.73	(0.94)-0.74 - 1.14	1.51 - 1
Magnesium	g / 100 g	< 0.3	0.30 - 0.49	(0.21)-0.50 - 0.80	0.81 - 1
Sulphur	g / 100 g	< 0.07	0.07 - 0.13	(0.65)-0.14 - 0.27	0.28 - 0
Iron	mg / g	< 10	10 - 29	(55) - 30 - 80	81 - 2
Manganese	mg / g	< 26	26 - 75	(125) - 76 - 174	175 - 2
Zinc	mg /g	< 13	13 - 52	(92)- 53 - 132	133 - 1
Copper	mg /g	< 2.0	2.0 - 4.9	(7.5) - 5.0 - 10.0	11.0 - 1
Yield	t / ha-1	< 21.82	21.82 - 25.94	25.95 - 34.20	34.21 - 3

Table 18. Leaf Nutrient Norms for Acid Lime

Nutrients	Unit	Range			
		Deficient	**Low**	**Optimum**	**High**
Nitrogen	%	< 1.24	1.24 - 1.52	1.53 - 2.10	2.11 -
Phosphorus	%	< 0.07	0.07 - 0.09	0.10 - 0.15	0.16 -
Potassium	%	< 0.60	0.60 - 0.96	0.97 - 1.66	0.67 -
Calcium	%	< 2.85	2.85 - 3.04	3.05 - 3.43	3.44 -
Magnesium	%	< 0.22	0.22 - 0.24	0.25 - 0.30	0.31 -
Sulphur	%	< 0.21	0.21 - 0.24	0.25 - 0.29	0.30 -
Iron	ppm	< 77	77 - 116	117 - 195	196 -
Manganese	ppm	< 10	10 - 21	21 - 64	64 -
Zinc	ppm	< 3.2	3.2 - 9.5	9.6 - 18.2	18.3 -
Copper	ppm	< 5.6	5.6 - 8.6	8.7 - 14.8	14.8 -
Yield	t / ha	< 13.7	13.7 - 15.6	15.7 - 19.4	19.5 -

Table19. Mean of Petiole N, P and K in High Yielding (> 100 T) Papaya

Nutrient	Index tissue	Boundary Line Optima	Average Optima
Nitrogen	6th Petiole 11th Petiole	2.181.38	1.521.31
Phosphorus	6th Petiole 11th Petiole	0.760.31	0.360.23
Potassium	6th Petiole 11th Petiole	4.965.30	4.934.17

Bhargava (1992)

Table20. Nutrient Guide for Banana – Robusta (*Musa* spp. group Cavandish subgroup Robusta)

Index Tissue	Unit	20th leaf stage	20th	32nd leaf stage
		N	**K**	
Leaf lamina	%	2.57	5.90	5.60
Petiole	%	0.95	5.60	4.60
At bud differentiation stage Third open leaf from apex			Bhargava and Reddy (1992)	

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Ma agi g Eroductio Co strai ts usi g Bio(ertilizers

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India is one of the largest producers of fruits in the world. The diverse agro climatic condition and varied soil types favour the cultivation of wide range of tropical, subtropical, temperate and arid zone fruit crops. However several factors influence the production potential of fruit crops and one of the important factors is the nutrient management. Integrated nutrient management with inorganic, organic and biological fertilizers is the best way to achieve maximum fruit production. Biofertilizers – a cost effective renewable energy source play a crucial role in reducing the inorganic fertilizer level and at the same time increasing the crop yield besides maintaining the soil fertility. The replenishment of nutrients lost by crop removal through the use of chemical fertilizers alone is not advisable in the long run, since their continuous use, impaired the soil health and productivity. Use of biofertilizer as a supplementary source of nutrient helps to check the emerging deficiency of the nutrients besides bringing economy and efficiency in fertilizer use. Biofertilizers can help in reducing the input of inorganic fertilizers for an extent of 25 per cent for obtaining the same or higher yield.

Biofertilizers are microbial preparations containing live or latent cells of specific microorganisms to apply to the seed or soil, so that the cells can multiply and bringing out the activities of nitrogen fixation or phosphate solubilization / mobilization in the root region or in association with the root system of crop plants.

Among the various nutrients, nitrogen is one of the key element for higher productivity. Nitrogenous fertilizers and biological nitrogen fixation represent the major inputs of nitrogen for crops. Although improved technologies of fertilizer nitrogen production and increased efficiency of fertilizer use by plants could make more nitrogen available for the plants, alternate technologies are being sought to reduce the dependence of plants on fertilizer nitrogen. The nitrogen-fixing microorganisms like *Rhizobium, Azospirillum, Azotobacter, Azolla,* cyanobacteria etc. fixes nearly 175 x 10^6 tonnes of N on the earth surface (Table 1) and it may be possible to meet a large part of nitrogen demand through proper manipulation of these organisms in crop production system.

Table 1. Annual Biological Nitrogen Fixation on Earth

N_2 fixing system	N_2 fixed (x 10^6 tonnes / year)
Legumes	35
Non-legumes	9
Permanent grass land	45
Forest & Woodland	40
Unused land	10
Total land	**139**
Sea	36
Total global nitrogen fixation	175

Although these microorganisms are available in the soil, their population, root colonization, efficiency in nitrogen fixation, survival under adverse condition etc. decides the necessity of artificial inoculation with selected strains of bacteria. The work carried out at TNAU for the past several years resulted in the identification of efficient strains of *Rhizobium, Azospirillum*, phosphobacteria and vesicular arbuscular mycorrhizae (VAM) which are used in large-scale production of biofertilizers. However, the usage and biofertilizer inoculation studies with horticultural crops are comparatively meager.

Azospirillum

Generally the nitrogen requirement of non-leguminous crops such as cereals, grasses and horticultural crops met partly from the activities of associative symbiotic bacteria – *Azospirillum*. *Azospirillum* is considered to be more efficient and it has been reported that *Azospirillum* inoculation increases the growth, nitrogen uptake and yield in number of crops. Field trials conducted at many places with different crops have revealed the significant amount of nitrogen fixation and there by saving the valuable N fertilizers. Experiments conducted over several years proved that 15 to 25 percent of nitrogen requirement could be met by inoculating *Azospirillum.*

Inoculation of *Azospirillum* enhanced the length and weight of bunches and also the number of hands and fingers in poovan banana (Table 2). The results showed that inoculation of *Azospirillum* caused 8.2 to 13.1 per cent increase in the yield of banana. Inoculation also enhanced the nitrogen, phosphorus, calcium and magnesium content of leaves and the reducing, non-reducing and total sugar content of fruits (Jeeva, 1987). Inoculation of *Azospirillum* at 75 per cent of fertilizer nitrogen recorded a cost benefit ratio of 1: 2.84 and it saved a quantity of 68 kg of fertilizer N per hectare in banana cultivation.

Table 2. Effect of *Azospirillum* on the bunch characters of banana cv. Poovan

T. No.	Treatments	Length of bunch (cm)	Weight of bunch (Kg)	No.of hands	No.of fingers
T1	110:35:330 g NPK / Plant	46.35	15.510	12.45	178.55
T2	T1 + Azospirillum	48.35	16.775	12.25	182.65
T3	82.5:35:330 g NPK / Plant	44.75	13.558	10.80	170.40
T4	T3 + Azospirillum	45.77	15.340	11.60	174.40
T5	55:35:330 g NPK / Plant	42.95	12.198	10.20	151.20
T6	T5 + Azospirillum	45.18	13.368	10.45	160.25

(Jeeva, 1987)

Wange (1996) recorded positive response of strawberry to *Azospirillum* inoculation and recorded significant increase in the yield (54%) at 150 kg N ha-1. Kennady (1998) observed increase in the plant height , root length and shoot , root dry weight in papaya due to *Azospirillum* inoculation.

Phosphobacteria

Microorganisms are also involved in the availability of phosphorus, the second most important nutrient required by crop plants. The phosphate solubilizing bacteria (PSB) solubilize the insoluble phosphates and make them available for crop plants in the rhizosphere region. Several soil bacteria and fungi notably species of *Pseudomo-nas, Bacillus, Penicillium* and *Aspergillus* etc. secrete organic acids and lower the pH in their vicinity to bring about solubilization of bound phosphates in soil. Increased in the yield of various crops were demonstrated due to inoculation of peat based cultures of phosphobacteria and saving up to 50 per cent of recommended level of P2O5 was observed in many experiments.

Vesicular Arbuscular Mycorrhiza (VAM)

Mycorrhiza is the mutualistic association between plant roots and fungal mycelia. Many graminaceous plants legumes and horticultural crops are highly susceptible to VAM colonization. The transfer of nutrients mainly phosphorus from the soil to the cells of the root cortex is mediated by intracellular obligate fungal endosymbiont of the genera *Glomus, Gigaspora, Acaulospora, Scleroscystis* and *Endogone* which posses vesicles for storage of nutrients and arbuscules for funneling these nutrients into the root system. The mycorrhizal fungi mobilize phosphates and other micronutrients like zinc, boron and molybdenum from adjacent soil to the root system through hyphal network.

Enhanced uptake of phosphorus and increased plant growth due to inoculation of soil with VAM fungi in horticultural crops such as citrus (Kleinschmidt and

Gerdemann, 1972), chilli (Bagyaraj and Sreeramulu, 1982), tomato (Fairweather and Parbery, 1982), chrysanthemum (Johnson *et al.*, 1982), asparagus (Hussey *et al.*, 1984), potato (Bhattarai and Mishra, 1984), marigold (Bagyaraj and Powell, 1985) banana (Iyer *et al.*, 1988), lettuce (Water and Coltman, 1989) and grapewine (Schubert *et al.*, 1990) has been observed.

Vinayak and Bagyaraj (1990) observed that inoculation of VAM fungi significantly improved the growth rate, plant height, stem diameter, plant biomass and nutrient content and also reduced the time taken for budding by 8 – 9 months in trifoliate orange. Papaya plants inoculated with *Glomus fasciculatum* and *G. mosseae* in nursery showed improved plant height, dry matter production as well as P, N and Zn concentrations with no or low levels of phosphorus application (Sukhada Mohandas, 1992). Kennady (1998) also reported that inoculation of *G. mosseae* recorded 77.7 per cent increase in root dry weight, 94.5 per cent increase in shoots dry weight over control under pot culture conditions in CO 5 variety of papaya.

Lin and Fox (1992) observed that application of *Glomus aggregatum* increased the plant dry weight of banana when the plants were fertilized with insoluble rock phosphate. Onkarayya and Sukhada Mohandas (1993) reported that inoculation of *G. fasciculatum* increased the plant height, root length, shoot dry weight, root dry weight and reduced mean shoot root ratio in the root stalks of citrus cultivars *viz*., Rough lemon, Rangpur lime, Trifoliate orange, Troyer citrange, Carizo citrange, Citrumelo and Cleopatra mandrin. In strawberry, VAM inoculation in combination with different levels of P increased the total fresh and dry shoot weight, leaf area and leaf number (Khanizadeh *et al*., 1995).

Increased phosphorus content in root and shoot of citrus seedlings up on inoculation with *G. fasciculatum* in unsterile soil was noticed by Manjunath *et al*. (1983). The increase in P content in strawberry plants (Hrselova *et al*., 1989), trifoliate orange (Vinayak and Bagyaraj, 1990) pear seedlings (Gardiner and Christensen, 1991), papaya (Kennady, 1998) due to VAM inoculation was observed. VAM inoculation also increased the uptake of zinc, cobalt, iron, magnesium and copper in a number of fruit crops.

Application of VAM inoculum during in vitro / in vivo rooting of the micropropagated shoots seems an attractive method for mycorrhization of the plants. Early inoculation of these plants also improves the plant survival and subsequent growth. This fact has been documented in fruit crops like grapevine (Mazzitelli and Schubert, 1989), apple and avocado (Branzanti *et al*., 1992; Vidal *et al*., 1992), pineapple (Guilleimin *et al*., 1992), strawberry (Vesteberg, 1992) raspberry (Varma and Schuepp, 1995) and banana (Pinochet *et al*., 1997; Pragatheswari, 2002)).

Combined inoculation

Combined inoculation of *Azospirillum* and VAM in papaya increased the plant height, plant girth and nutrient content in leaves under reduced level of N and P with an increased fruit yield of 10.07 per cent over control (100% N and P) (Kennady, 1998). (Table 3).

Table 3. Effect of combined inoculation of Azospirillum and VAM on fruit yield of Papaya (Co.5)

T. No.	Treatments	Fruit yield (tonnes / ha)	% increaseover control
T1	100% N + 100% P	148.85	-
T2	100% N + 100% P + Azospirillum	160.43	7.78
T3	75% N + 100% P	135.60	-
T4	75% N + 100% P + Azospirillum	155.08	4.19
T5	100% N + 75% P	136.38	-
T6	100% N + 75% P + G. mosseae	154.64	3.89
T7	75% N + 75% P	123.86	-
T8	75% N + 75% P + Azos. + G. mosseae	163.84	10.07

(Kennady, 1998)

Similarly combined inoculation of phosphobacteria and VAM recorded higher bunch height, bunch weight, hand number and total number of fingers (Pragatheswari, 2002) (Table 4). Judicial combination of nitrogen fixer, phosphobacteria and VAM improved the yield of several crops besides reducing the requirement of chemical fertilizers. In many experiments conducted in Tamil Nadu for several years, substantial yield increase was observed (10-15 per cent) besides saving of 15 to 25 per cent fertilizer N and P. Recently, a new formulation of biofertilizer namely 'Azophos' has been developed by mixing efficient strains of both *Azospirillum* and phosphobacteria. This helps the farmer to derive more benefit by using a single packet of inoculum containing both the N_2 fixer and P solubilizer which is easy for application.

Table 4. Influence of phosphobacteria and VAM on the growth of banana (Dwarf Cavendish) at graded levels of P under field condition

T. No.	Treatments	Length of bunch (cm)	Weight of bunch (Kg)	No. of hands	No. of fingers
T1	100 % P alone	61	16.0	11	198
T2	75 % P alone	55	14.2	8	120
T3	100 % P + Phosphobacteria	72	16.5	12	264
T4	75 % P + Phosphobacteria	68	16.0	9	162
T5	100 % P + VAM	80	19.0	13	299
T6	75 % P + VAM	68	17.6	10	210
T7	100 % P + Phos. + VAM	84	19.5	14	350
T8	75 % P + Phos. + VAM	74	18.2	12	264

(Pragatheswari, 2002)

Conclusion

Under the integrated nutrient management system, the cost of cultivation is held within the reach of the average farmer since the crop requirement is partly met from organic sources like farm yard manures, green manures, legumes and biological fertilizer. The potential nitrogen fixing biological systems like *Azospirillum*, phosphorus-solubilizing bacteria such as *Bacillus* and *Pseudomonas* and the vesicular arbuscular mycorrhizae plays a triggering role in nitrogen and phosphorus nutrition of horticultural crops. It is evidently clear now that the application of biological fertilizer greatly involved in the accumulation of soil enzymes, which directly reflects on soil fertility index. The effective utilization of biofertilizers for crops not only provide economic benefits to the farmers but also improves and maintain the soil fertility and sustainability in natural soil ecosystem.

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Co strai ts i Orga ic 7ruit Eroductio a d their Ma ageme t

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Importance of organic farming

Organic agriculture started in 1920 in Europe and struggled a lot in midst of chemical lobby; environmental concern was neglected ; abundant use of chemical fertilizers, pesticides and weedicides resulted in increasing desertification, degradation of soil health and fragility of plants. The effect of prolonged and judicious use of chemicals on soil has resulted in human hazards and pollution of the environment.

In agriculture, sustainability means development not only in terms of output, but also the socio-economic and ecological parameters. According to United Nations Development Programme (UNDP), New Delhi, safeguarding national food security means improving quality of the life of farming community by ensuring no further depletion of natural resources base. Organic agriculture is one of the most widely practiced, diversified conventional farming as a tradition, still the question is whether we should go for it or not.

Organic cultivation of fruits

Organic fruit production essentially excludes the use of many inputs associated with modern farming, most notably synthetic pesticides and fertilizers. To the maximum extent possible, organic farming systems rely upon crop rotations, crop residues, animal manures, legumes, green manures, off-farm organic wastes, mechanical cultivation, mineral- bearing rock powders and biological pest control. These components maintain soil productivity and tilth, supply plant nutrients and help to control insects, weeds and other pests.

Constraints in organic fruit production

The market potential for organic fruit produce from India for export and domestic market shows excellent scope. However, there are several obstacles for successful production and marketing of organically grown fruits. The major constraints faced by the farmers in production and marketing include

- Lack of awareness on the scope of organic farming
- Inferior varieties with inconsistent characters.
- Reduction in honey bee population due to indiscriminate use of chemicals which leads to lack of pollination in fruit crops.
- Inadequate supply of good quality planting material
- High incidence of pest and disease
- Drastic reduction in cattle population
- Weather dependent production systems
- Seasonality of production and drastic price fluctuation.
- Inefficient resource management practices
- Low productivity and high cost of production
- Limited availability of land and support services for large scale commercial production
- Limited processing and value-addition activities
- Higher percentage of post-harvest losses
- Lack of co-ordination among the farmers and cluster farming activities
- Inadequate marketing facilities and poorly-operated distribution network
- Lack of infrastructure facilities like cold storage, vacuum packing units, processing units etc.
- Non-availability of information on marketing
- Lack of support from the Government agencies and other relevant departments in the form of subsidy and financial assistance
- Irregular supply of organic products

- High certification cost
- Lack of government policies to support organic farming

Management practices for organic fruit production

Site selection

Growing fruit crops offers an advantage to farmers interested in sustainable agriculture. Because fruit plantings are perennial, the soil may not require additional tillage or cultivation beyond that needed at establishment, thereby minimizing soil erosion. Because the potential for erosion is low, hillsides and other sites unsuitable for tillage agriculture can safely and successfully produce fruit crops.

Crop selection

Environmental constraints (climate, presence of certain pests and diseases, suitable soils, etc.) can greatly impact the suitability of a given site or even a bioregion for organic production of a given fruit crop. Generally speaking, some perennial fruits are easier to grow organically than others. The small fruits (berries for example), seem easier to grow organically than the tree fruits in almost all locations. Lastly, successful organic fruit growing may depend largely on whether the venture is for home production or for commercial sales.

Varietal selection

Because the plants are perennial and require a considerable investment in both time and money, it is important to start fruit planting with optimum varieties for location and markets.

Aphid-resistant berries, *Phylloxera*-resistant grape rootstocks, wooly aphid-resistant apple rootstocks, mite-resistant strawberry cultivars, and nematode-resistant peach rootstocks are available. As important as this resistance is, there is no cultivar of any fruit species with multiple insect pest resistance; therefore, means other than resistance will have to be employed to protect fruit plant from a complex of several pest species.

Site preparation

In general, fruit crops do not require highly fertile soils for good production. A nutritionally balanced soil, proper soil pH and plentiful amounts of organic matter are the fundamentals of an organic fertility management plan for fruits. Preplant soil improvement for organic fruit plantings is typically accomplished through some combination of cover cropping/green manuring and the use of imported materials, which may include manures, compost, rock powders and organic wastes.

Of particular importance at this stage is the application of required amounts of lime or sulphur. Most fruit plants perform best around pH 6.5, although they tolerate a pH range between 5.5 and 7.2. Blueberries are an exception. They require an acid with oil-ideally pH 4.8 to 5.2. Soil testing should also be used to guide applications of manures and other rock powders to avoid nutrient imbalances.

Soil solarization

Another technique for site preparation is soil solarization. The process involves placing transparent polyethylene plastic on moist soil during hot summer months to increase soil temperatures to levels lethal to many pests. Solarization suppresses weeds and eliminates many potential soil disease and nematode problems.

Mulching

After a planting is established, mulching with organic materials such as straw, leaves or sawdust can provide significant weed suppression. Application of mulch varies somewhat with crop. In strawberries for instance, mulch might cover entire aisles between rows or only be placed next to the bed to inhibit encroachment by creeping weeds. In vineyards and orchards, mulch might be placed only under individual trees or vines or along the entire row, ideally extending to the drip line. In mulberries, sawdust mulch is commonly spread along the entire row with extra sawdust mounded around the canes, often to a depth of 8 or more inches. In addition to controlling weeds, mulching with organic materials improves the soil by enhancing soil aggregation and water availability.

Leaves of coconut (*Cocos nucifera*), palmyra (*Borassus flabellifera*), kekuna (*Aleurites triloba*) Gliricidia (*Gliricidia maculata*), and wild sunflower (*Tithonia diversifolia*) are used for shading the plants soon after planting. Live supports are recommended for passion fruit trellising (Heenkenda and Punchikumari, 1991).

Organic fertilization practices

Harvested fruit, removes relatively few nutrients from the soil, compared to other crops. Therefore, a significant amount of fertility needs of fruit crops can be met through cover crop management and organic mulches in systems which use them and by the application of lime and other slow-release rock powders at the preplant stage. Still, supplementary fertilization is often required for optimum growth and production.

Recommendations of organic nutrition for fruit crops (Ariyaratne, 2000).

Crop	Time of application	Type of organic manure	Amount (kg/plant)
Banana	Basal dressing	Compost + kitchen ash, cattle manureor Farm Yard ManureCoconut husk layer beneath the pit	5
	Soon after planting	Coir dust layer as a mulch	
	Once in 2-3 years	Ground dolomite	0.45
	After planting	Mulching with straw, coir dust, saw dust, paddy husk, banana residue	Ample amount
	Top dressing with organic manure at 3 month intervals	Poultry manure orCattle and other animal manure (or)Green manure	3-5 5-10 7-10
Papaya	Basal dressing	Poultry manure (or) Cattle manure andGround dolomite	5-10 4-55
	Top dressing with organic manure at 3 month intervals + mulching	Compost orCattle manure +Straw or/and crop residues or/and any type of animal manure or live mulch	5-10 4-5 Ample amount
Pineapple*	Basal dressing	Any organic manure	
	Mulching as top dressing	Coir dust, saw dust, cadjan leaves, rice husk, banana trunk chops or straw +Ground dolomite	Ample amount 2-5 t/ha
Passion fruit	Basal dressing	Cattle manure or Poultry manure	5-10
	Top dressing	Cattle manure or Poultry manure	3-4

* Pineapple crop residues should be recycled with utmost care as pineapple wilt virus may be transmitted through mealy bugs.

Organic weed management

Research indicates that without some form of weed control in the fruit planting, crop yields and plant vigour will be greatly reduced. In organic farming, weed control is only one goal of a weed management system for perennial fruit crops. A good organic weed management plan should present a minimum erosion risk, provide a "platform" for the movement of farm equipment, not impact adversely on pest management or soil fertility, while minimizing weed competition for water and nutrients. This philosophy has already been demonstrated in discussions regarding three effective weed control tools: cover crops, mulches and soil solarization.

Organic insect and mite pest management

A major distinction between pest management in perennial fruit crops and in annual crops is that crop rotation is not an option (strawberries and to a lesser extent, brambles, are possible exceptions). The long term nature of fruit growing allows for the possible build up of a pest population over time. Conversely, it is also possible for such stable agricultural environments to sustain populations of beneficial organisms.

Plant health and vigour

Though it is sometimes overstated, maintaining the plant in general health and good vigour is important in pest management. For fruit plants, this adage is more applicable to indirect pests (those pests that feed on foliage, stems etc.) than to direct pests (pests that feed on the fruit). For instance, an apparently healthy plum tree may set a good crop of fruit, yet lose it all to the plum. On the other hand, the same tree might suffer significant defoliation by caterpillars early in the season; yet, if it is in good vigour, it can compensate and bounce back quickly still producing a marketable crop that year. There are some cases where general plant health and freedom from stress does impart a form of "resistance" not technically genetic resistance to certain pests. Two examples are apple trees in good vigour actually smothering with sap or casting out invading flathead apple tree borers and plants not suffering drought stress being much less attractive to grasshoppers.

Biological control

Biological control refers to the use of living organisms to control the population of a pest. Examples of beneficial arthropods that have been used to control pests in fruit crops include the predatory mites *Phytoseiulus persimilis* and *Metaseiulus occidentalis*, which attack spider mites; lady bird beetles and green lacewings which feed on aphids and *Trichogramma* wasps, which parasitize the eggs of several pests including codling moth. Bio control agents for white flies and thrips are being worked out. There has been recent interest in the use of entomopathogenic organism as bio control agents of pests. There are few surveys done to identify pathogenic agents of insect pests and nematodes. Bio- control agents are raised in mass scale on tea waste, paddy husk and molasses. In the laboratory and green house studies revealed that different isolates of *Trichoderma* could be effectively used to control *Schulorotium rolfsii* (Cocoyam root rot) (Kudagamage, 1999).

Organic and bio pesticides

The bacterium *Bacillus thuringiensis* (Bt) is an example of a commonly used biological insecticide. Bt is not as effective against lepidopterous pests that spend their larval stage feeding inside stems, crowns, trunks, or fruit, etc. (e.g., peach tree borer, codling moth, grape root borer, etc.). Other microbial insecticides include *Bacillus popilliae* for Japanese beetle grubs, a granulosis virus for codling moth, and insect parasitic nematodes for grubs and wireworms.

Organic disease management

Several formulations of the fungus *Trichoderma harzianium* are now come to market as a control for grey mold (*Botrytis*). Other biofungicides now available include a control for powdery mildew in grapes and a protectant against tree wound pathogens.

Organic farming technologies

Green manuring

Soil moisture management and plant nutrition are important aspects of fruit production (Wijesekara and Heenkenda, 2001). Use of green manure crop is one of the main requirements of organic fruit production. Many potential green manure crops have been recommended as organic manure for fruit production and plant propagation.

The green manures used in organic fruit production are as follows. (Nagarajah and Amarasiri, 1977).

Botanical name	Nutrient composition % dry basis			
	N	P	K	C:N
1. Leaves used:				
Aleurites triloba	2.34	0.17	2.65	19
Azadirachta indica	2.38	0.20	1.30	20
Borassus flabellifera	1.62	0.10	1.07	32
Cerebera adollam	2.31	0.10	1.8	22
Erythrina lithosperma	4.00	0.29	3.95	14
Gliricidia maculata	4.15	0.27	3.00	12
Tamarindus indica	1.59	0.19	1.19	27

Botanical name	Nutrient composition % dry basis			
	N	P	K	C:N
2. Leaves and stems used:				
Calotropis gigantean	3.86	0.30	3.45	11
Cassia occidentalis	4.91	0.20	1.87	12
Croton lacciferus	3.5	0.30	2.15	15
Tephrosia populnea	3.73	0.28	1.78	11
Thespesia populnea	3.43	0.25	3.30	14
Tithonia diversifolia	3.84	0.29	5.90	14

Other sources of organic manures and methods are indicated below. Detailed informations can be had from the author.

A. Biodynamic Compost

Biodynamic compost is prepared using green wastes, dry wastes, farm yard manure, rock phosphate, dolomite, jaggery, and fresh cow dung and neem cake under aerobic condition above the ground under shade in a 12.5¢ x 4¢ x 4.5¢ size compost heap with the following ingredients.

Green wastes	-	150 kg (11 layers)
Dry wastes	-	100 kg (11 layers)
FarmYard Manure	-	250 kg (8 layers)
Rock Phosphate	-	15 kg
Dolomite	-	15 kg
Jaggery	-	6 kg
Fresh cow dung	-	10 kg
Neem cake	-	20 kg
Panchagavya 3%	-	5 lit
Azospirillum	-	1 kg
Phosphobacteria	-	1 kg

While making the compost heap, rough vegetation is spread as a basal layer for better aeration and then green and dry wastes were spread in alternate layers. In each layer, organic solutions prepared by mixing fresh cow dung, jaggery and water is sprinkled. For every two layers, dolomite, Rockphosphate, Panchagavya, neem cake, biofertilizers like *Azospirillum* and *Phosphobacteria* and farm yard manure are spread. Biodynamic preparations are prepared from fermented flowers of homeopathic plants of yarrow (*Achillea millefolium*), chamomile (*Chamomilium nobile*), stinging nettle (*Utrica dioica*), oak bark (*Quercus robur*), dandelion (*Taraxacum officinale*) and valerian (*Valeriana officinalis*). Each of these biodynamic preparations are applied at the rate of 1 g into the heap by making random holes on the top of the heap and covered with cow dung. Finally the compost heap is covered with soil and the heap is kept moist by regular watering. After 60 days the entire heap is turned upside down and mixed thoroughly and left for 4 to 5 months for composting. This compost is applied at the rate of 5 t/ha at the time of land preparation.

B. Biodynamic preparations

Biodynamic preparations are special organic preparations, suggested to establish an advanced method of recycling organic matter in bulk. The preparations help regulate the processes and life in soils, in composts and in the interrelationship of plant life to its near and distant environment. The preparations applied in small quantities act as stimulants which influence the compost and manure fermentation, the relationship between plants and nutrient elements, and especially the quality of vegetable produce.

There are eight biodynamic preparations of which horn manure and horn silica are used for field sprays for soils and plants and remaining six preparations are used for applying to manures and composts which are discussed already in the biodynamic compost preparation methods.

B.1 Horn Manure

Horn manure is prepared by keeping the cow dung in cow horns and fermenting them before use. It is stored in the dark in a slip lined pottery vessel, corked and used as a spray for soil.

Horn manure should be sprayed on to the soil at the time of land preparation at the rate of 4 kg/ha in 20 litres of water. This manure is sprayed after potentising it by stirring it for an hour in clock-wise and anti-clock wise direction repeatedly till a deep vortex formed every time.

B.2. Horn Silica

Quartz is ground to fine powder and mixed with water to make a thin "dough". This is stuffed tightly, into female horns and buried underground in about 3 deep during summer. This preparation is stored in sunlight.

Horn silica should be applied at 65 days after sowing/ planting as foliar spraying at the rate of 2.5 g/ha by dissolving in 50 l water. This manure is sprayed after potentising it by stirring it for an hour in clock-wise and anti-clock wise direction repeatedly till a deep vortex is formed every time on the soil, 3 days before full moon or moon opposite Saturn before sowing. It is sprayed again after the emergence of first true leaves to protect plants from fungal diseases.

B.3. Cow pat pit manure

It is prepared by fermenting fresh cow dung, eggs hell powder and rock dust along with the homeopathic biodynamic plant preparations. This is applied as foliar spray at the rate of 4 kg/ha by dissolving in 20 lit water.

C. Tree paste

Take equal portion of CPP manure, cow dung, rock dust and clay, make it as a paste and smear it in stems of pruned trees.

D. Panchagavya

Panchagavya an organic preparation is prepared with the following ingredients

Cow dung	:	7 kg
Cow urine	:	10 litres
Water	:	10 litres

After 15 days, the following ingredients were added.

Cow milk	:	3 litres
Cow curd	:	2 litres
Cow ghee	:	1 litre
Tender coconut water	:	3 litres
Jaggery	:	3 kg (or) Sugarcane juice
	:	3 litres
Banana	:	12 nos

The ingredients are mixed thoroughly both in the morning and evening and within twenty-five days the panchakaviyam is ready for spray. 3% solution (3 ml in 100 ml) was sprayed to the fruit plants at monthly interval. It was found to increase the yield and give resistance for pests and diseases.

E. Dasagavya

Dasagavya is prepared by using cow dung, cow urine, ghee, curd, cow milk and the leaf extracts of commonly available weeds. In hilly areas, the weeds like *Artemisia nilagirica*, *Leucas aspera*, *Lantana camera*, *Datura metel* and *Phytolacca dulcamera* and in plains *Azadiracta indica*, *Tephrosia purpurea*, *Vitex*, *Leucas aspera* and *Datura metel* can be used. Cow dung (7 kg), cow urine (10 lit) and water (10 lit) are mixed thoroughly and kept for 15 days with regular mixing in morning and evening. After 15 days, 1 lit of each leaf extract and 3 lit cow milk, 2 lit well fermented cows curd, 1 lit cow ghee, 3 lit tender coconut water, 3 kg jaggery and 12 Nos of well ripened Poovan banana are added. The ingredients are mixed thoroughly both in the morning and evening and kept for 25 days. Dasagavya 3 % should be sprayed 5 times at 15 days interval from one month after planting.

F. Homa farming

The product of Homafarming called Agnihothra ash, is prepared by burning dry cow dung, cow ghee and unbroken raw rice in inverted copper pyramid plate at the time of sunrise and sunset. Adoption of homa farming in orchards field completely sterilised the environment and clears the area from pathogens. In addition the ash collected from the pyramid shaped copper plate is mixed with cow urine for fermentation and sprayed for disease management. Foliar spraying of Agnihothra ash (200 g of Agnihothra ash in 1 lit. cow urine kept for 7 days for fermentation and then diluted in 10 lit. water) should be done three times at monthly intervals.

G. Biofertilizers and biocontrol agents

1. Acid tolerant Biofertilizers, *Azospirillum* and *Phosphobacteria* 5 kg each/ha are applied at the time of land preparation
2. *Trichoderma viride* at the rate of 2.5 kg/ha is applied at planting.
3. *Pseudomonas fluorescens* at the rate of2.5 kg/ha is applied at planting
4. *Metarrhizium anisopliae* at the rate of 20 kg/ha is applied at planting
5. *Pseudomonas fluorescens* 0.5% is sprayed 3 times at monthly intervals.

6. *Bacillus thuringiensis* 2 g/lit is sprayed at primordial stage twice at weekly intervals.

H. Vermicompost

Vermicompost at the rate of 2.5 t/ha is applied at the time of land preparation.

I. Vermiwash

The water soluble components from vermicompost is collected by passing water slowly through the worm beds or by simple suspension of vermicompost in water. Vermiwash 10% is sprayed 5 times at 15 days intervals from one month after planting.

J. Botanical sprays

i. Nettle leaf extract

One kg of nettle leaf is fermented in 1 lit of cow urine for 10 days. Then the extract at 10 % is sprayed 15 days interval.

ii. Garlic extract

Two kgs of garlic, 1 kg of green chillies, 10 gram of asafoetida are mixed in cow urine and left for 10 days. Garlic extract 10% is used as foliar spray for the management of sucking pests and foliar diseases.

iii. Insecticidal botanical baits

Poison baits are prepared from pyrethrum flowers for the management of cutworms. Pyrethrum bait is prepared from 2 part pyrethrum flower, 1part wheat bran and 1 part jaggery slurry.

K. Manchurian Tea

Manchurian tea, a traditional fermented tea, has gained popularity among the tribes in Manchuria due to its health promoting properties against diabetes, arteriosclerosis, gout, rheumatism, intestinal problems, hypoglycemia and high blood pressure. Manchurian tea, which is a symbiont of *Acetobacter xylinum* and *Saccharomyces ludwigii*, is grown on black tea, which produces various acids, enzymes and some antibiotic substances. This extract is used in biodynamic organic farming system. Culture filtrate of Manchurian tea @ 5% concentration is sprayed for improving the growth of the plant and for the management of foliar diseases.

L. Fish concentrate

Fish makes excellent minerals tonic manure. It is broken down into a liquid which is then diluted usually about 1 part of fish to about 100 parts of water. One or two pints of the concentrate is used per acre (about 1 litre per hectare). It is sprayed on to the plants in order to take advantage of the increased nutrient uptake at that time. In fruit crops, it can be applied as often as once a week.

M. Liquid Seaweed Concentrate

Seaweed not only contains all the elements and trace elements but also a growth hormone. The concentrate is used in the same way as the fish but the dilution rate is only about 1 in 10.

N. Planting date

In the biodynamic treatment planting should be done based on the solar constellations and the date of planting is fixed in accordance to the vedic tradition.

Suggestions

Organic fruit production could be promoted and developed further in the years to come by eliminating the constraints mentioned earlier with the involvement and commitment of the organic growers, scientists, government agencies, NGOs and consumers.

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Approaches to Ma age Ehysiological Eroblems due to Nutrie t De(icie cies i 7ruit Crops

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Introduction

"Indian fruit culture suffers from neglectosis" and in this, lack of nutrient management in Indian fruit orchards is a rule rather than exception – Dr.H.D.Chapman. Nutrient refers to all those compounds required by an organism as a source of body building material and energy, without which, it will not be able to complete its life cycle. The nutrient elements required by the plants are classified into macro and micronutrients, the former being required in larger quantities and the latter in smaller doses. Lack of any one of these elements is reflected in defective growth or yellowing of leaves. Micro-nutrient deficiency in Indian orchard soils have been at increase and quite extensive, especially of Zn, Fe, B etc. There are a number of distinct disorders caused by some micronutrients in fruits like : 'fruit cracking' in citrus, pomegranate and litchi due to 'B' deficiency, internal fruit necrosis in mango, aonla, jack fruit due to 'B' deficiency, 'bitter pit' in apple due to Ca – deficiency, 'little leaf interveinal chlorosis' in guava, citrus due to 'Zn' deficiency, 'yellow spot' disease in citrus due to 'Mo' deficiency. The deficiencies may be caused either by the lack of a particular element in the soil or by its fixation in the soil, thus becoming not available to the plant. Physiological problems in fruit crops are summarized below.

1. Banana

NITROGEN : Restricted growth and reduction in the rate of leaf production are the most common symptoms of N deficiency. The underside of midribs and leaf petioles of Gros Michel recorded development of pink colours on the underside of midribs and leaf petioles at the initial stages of nitrogen deficiency. In Dwarf Cavendish banana, the leaves were found to be pale green in colour, and the whole plants of cv.Robusta became pale green due to 'N' deficiency.

Management : Supplying 'N' at rates varying between 75 and 300 kg / ha. 'N' should be applied in a band around the banana plant, approximately 50 cm from the corm.

POTASSIUM : Marginal scorching is the typical disorder noticed in banana due to potassium deficiency. Banana is a heavy feeder of potassium. Premature yellowing of lower leaves is the conspicuous symptom of the deficiency. Older leaves become yellow at the tips and distal margins. Discolouration spreads very rapidly from the margins inwards until the whole leaf is withered. The whole leaf becomes yellow within one or two days. The yellow leaves dry up quickly and the leaf tips curl inwards. Such leaves do not collapse at the petiole but typically stands out from the pseudostem in their normal positions. Leaf emergence is progressively slower to appear. Successive leaves are also smaller. In severely deficient plants, brownish water-soaked tissue is present in the centre of the corm. Similar patches also develop at the base of the petioles. The deficiency is also characterized by very rapid yellowing (orange – yellow) of leaves numbered 5 or 6 (the leaf numbered 1 is the last completely unfurled leaf emitted). The midrib of these leaves is very often broken two-thirds of the way along its length. The symptoms may also appear where the soil is sufficiently rich in potassium. In such cases, it is possible that the element is being poorly absorbed owing to a root system, which is inadequate or in poor condition. The symptoms often appear at the time of flowering. When the plant has the highest demand for potassium. Potash deficiency is aggravated by high pH, by root damage, by drought and heavy potash removal from the soil.

Management : Potassium deficiency can be rectified by foliar application of one per cent muriate of potash (potassium chloride) in addition to recommended dose of fertilizer.

MAGNESIUM : The early symptoms of magnesium deficiency are marginal chlorosis of the older leaves, extending increasingly towards the midrib. Part of the lamina always remains green on either side of the rib. As the leaf gets older, it becomes golden – yellow, with numerous necrotic patches. As they die, the petioles and leaves rot, giving off a smell of decay. The disease called **blueing** is often associated with magnesium chlorosis. It is due to the imbalance of potassium and magnesium. The main symptom of the disease is purple-blue and brown marbling, which is visible on the underside of the petioles, midribs and main veins.

Management : Apply magnesium sulphate @ 50-100 kg / ha immediately after noticing the symptoms, or give foliar spray of 0.5% $MgSO_4$.

SULPHUR : The symptom is characterized by retarded colouration of the young leaves. Lack of colour in the young leaves may intensify and lamina edges become completely white. The heart leaf is white. The leaf blades become very soft and delicate and tear off very easily. If the sulphur deficiency persists on the adult banana plant, the newly developing leaves will be poorly developed. The surface area of the leaf blades gradually diminishes until the leaves obtained are reduced to just the main vein.

Management : Apply ammonium sulphate @ 100 g / plant to correct the deficiency.

CALCIUM : The symptoms of calcium deficiency are reduction in the length of the leaves and a slowing down of the rate of emission. Later, thickening of the secondary ribs is noted on the younger leaves, giving them a crinkled appearance. Finally, there is interveinal chlorosis, which is dentate in form, directed towards the midrib. The chlorosis develops into necrosis, which may occur in the middle of the blade and form button holes.

Management : Apply 0.3 % of calcium chloride as foliar spray.

ZINC : Zinc deficiency appears on young plants as interveinal discolouration in the form of chlorotic stripes alternating with patches that have remained green. The leaves will appear as papery white in color. It can be corrected by applying zinc sulphate 15 – 30 g / plant.

BORON : The main symptom of boron deficiency is the appearance of very fine streaks perpendicular to the secondary veins. These streaks can be seen as transparent on the underside of the leaves. This is called as laddering effect. This deficiency may be corrected by applying borax 20 g / plant .

COPPER : Copper deficiency is normally noticed in red soil after three months of planting. The deficiency is characterized by the unfurling of the young and developing leaves giving a tail-like appearance, which is commonly called **whipping of banana**. The leaves show twisting symptoms. Telescoping of the further coming leaves of the plant can be seen. The deficient plants produce symmetrical, very short and narrow leaves. Reduction in length and breadth of leaves may be 33 to 50 per cent. The leaves become light green or yellow. In severe cases, leaves also become white. Chlorophyll content is greatly reduced. Starch formation is affected. The plants with acute deficiency, do not produce bunches. If at all bunches are produced, they will be very small with few fingers. The fruits are small and fetch very low price.

Management : Application (pouring) of 0.5 – 1.0 % copper sulphate solution in the crown region of banana (leaf funnel) with the help of a mug (if the plants are short) or with hand operated knapsack sprayer (after removing nozzle). The same copper sulphate solution can be drenched in the root zone of banana plants at 2 to 3 litres per plant. This may be repeated 5 to 6 times at 10 days interval depending upon the deficiency level.

MANGANESE : It is characterized by marginal chlorosis developing along the main transverse veins, leaving the interveinal areas greener and giving the leaf a striated appearance from the edges (chlorosis in a comb form). Manganese deficiency can be corrected with the soil application of 40 kg / ha of manganese sulphate.

Physiological disorders due to nutrient deficiencies

"Yellow pulp" is physiological disorder, which shows premature and abnormal development of immature banana fruits. This malady is associated with excess of 'K' in relation to 'N'.

Remedial measure : Magnesium and sulphur application reduces the incidence.

'Degrain' is the drooping of ripe banana fruits from the bunch due to the rotting of the pedicels. It was observed that a high N / P ratio in the manure tends to thicken the stalks and flatten the central cylinder and markedly increased the susceptibility to tannin oxidations.

Remedial measures : Enhanced application of phosphorus (DAP) would alleviate the disorder or foliar spray of 0.5% KH_2PO_4 after shooting.

2. CITRUS

NITROGEN : The young leaves remain undersized, thin, fragile and pale in colour. Yellow veining of Valencia orange, sometimes called winter chlorosis, has been found to be associated with nitrogen deficiency. Inadequate N in Valencia orange show thinness of foliage and premature leaf abscission. Nitrogen starved plants retain their foliage for a longer time. Trees grown with limited supplies of nitrogen may appear nearly normal but are undersized. Considerable twig die-back occurs and the trees look bushy. Such trees are mostly unfruitful or highly erratic in bearing behaviour. They bloom sparsely, flushes irregularly and produces very limited twig and leaf growth.

Corrective measures : Apply recommended dose of N.

POTASSIUM : The deficiency results in twisting, curling and puckering of leaves. Leaves may show non-uniform yellowing and bronzing. Twig growth is weak. Trees are stunted. Fruit size gets reduced.

Management : Foliar application of 5% KNO_3 or 2% KCl could effectively alleviate any visual symptoms of K deficiency and markedly increased K content of leaves.

MAGNESIUM : The deficiency is chiefly the result of accumulation of imbalanced availability of calcium and potassium in the soils grown with continuous imbalance manuring with potassium or calcium containing fertilizers. Symptoms are prominent on the older leaves. The yellowing is prominent on both the sides of the midrib and extends from the base to apex of the leaf. The green portion tapers towards the tip of the leaf so that an inverted "V" shape results.

Management : Apply $MgSO_4$ @ 500g / tree as basal dose + foliar sprays of $MgSO_4$ @1kg / 100 lit. of water.

IRON : Iron deficiency is a common problem in alkaline soils. Deficiency results in a net work of green veins against light green or yellowing background. In extreme cases, the entire leaf becomes chlorotic with the veins remaining green. In advanced stages, the veins loose the green colour. Growth is retarded and yield of fruit are reduced.

Management : Apply Ferrous sulphate @ 500 g / 100 lit. of water as foliar sprays twice at 15 days interval after the appearance of the symptoms.

ZINC : Deficiency of zinc in citrus is an important disorder and known as **foliocellosis or frenching or frenched leaf or mottled leaf**.

Symptoms : The most striking effect of zinc deficiency in citrus is characteristic irregular and chlorotic leaf spots, small leaves on terminal growth and severe dieback of twigs. The first leaf effects are fading of chlorophyll in mesophyll areas between the veins, within the main veins midribs and bands of fringes adjacent to these remaining green. As a result, a series of irregular, chlorotic blotches and patterns appear on the leaves. Chlorosis is more prominent and abundant on the sunny side to the tree. Leaves are drastically reduced and become narrow, pointed and chlorotic. Stem elongation is reduced and internodes shortened which results in small leaf clusters producing a rosette appearance of twigs. Weakened terminal growth results in marked twig die-back. Twig severely deficient in zinc become open and bushy in appearance. The small, narrow and pointed leaves often stand more erect. A fruit size is also decreased and often lighter in colour. Fruits may be misshapen. Fruit is woody, dry, insipid and low in acid and vitamin C content.

Causes : Zinc deficiency is especially prevalent in acid – leached sandy soils, where the cause is commonly low-zinc content. It also occurs widely in alkaline soils, where low zinc solubility is the chief cause. High phosphorus and nitrogen fertilizers (especially alkaline forming type) may increase severity of zinc deficiency. Shortage of organic manures, use of chemically pure fertilizers, imbalances from other elements and lack of zinc application in fertilization programme also cause zinc deficiency.

Management : Zinc deficiency in citrus can be corrected by spraying with 0.2 per cent zinc suphate on young flushes.

BORON : Boron deficiency in citrus (lime) is commonly known as **hard fruit or stony fruit.** Trees deficient in boron produces distorted leaves. Mature leaves show thick and corky veins and midribs. Leaves are twisted. Fruits of all ages show deficiency symptoms. Many fruits set but fall of in first 3 or 4 months. The few fruits that persist are insipid and low in juice content. Young fruits tend to lose green colour in large area and shed excessively. Fruits tend to be hard and misshapen. The white portion of the rind (albedo) shows brownish discolouration (due to presence of brown gum pockets) and is thickened. Seeds are few and the centre of the fruit has gummy excretions. The deficiency symptoms are prominent on older leaves. Margins of the leaf turns brown, the veins turn yellow. Fruits become thickened and corky and split along the length (fruit cracking). Fruits have thickened rind. Brown gum pockets are seen in the albedo and around the seeds, which may be aborted. Seeds may be dark coloured.

Management : Spraying borax 0.25 per cent three or four times at 10 days interval corrects the deficiency. Soil application of borax at 25 to 50g per tree along with NPK fertilizers also corrects the boron deficiency.

COPPER : Copper deficiency in citrus is variously called as **exanthema, red rust, die-back, multiple bud** or **peach leaf conditions.** The physiological disease caused by Cu shortage is also commonly known as foliocellosis. Deficiency results in dark green leaves borne on 'S' shaped twigs. Shoots that develop laterally may show aphotrophic response by turning upward at their outer ends, giving rise to 'S' shaped conditions. Later, yellowish blotches appear on the shoots just below the leaf nodes. These areas indicate the stoppage in the phloem so that the carbohydrates cannot move from the leaves into the stem and fruits. Small swellings or bumps develop along the stem simultaneously with yellowish blotches. When these swellings are punctured, brownish gum in the bark region oozes out. This condition is called exanthema. Copper deficiency is seen in situations, where zinc, iron and manganese deficiency is seen and copper-based fungicides are not used. Lack of copper produces stained terminal branches, stained fruits, and small gum pockets in the twigs bark excretion. The deficiency is frequently noticed in fruits than in foliage. The fruits will show brown gum soaked eruptions with irregular blotches around central pith. This can be seen on young and mature fruits. Often there are brown or reddish brown gum excretions on rind, sometimes with a small to large splits in the rind. On leaf, the deficiency symptoms resemble like excess of N with long, vigorous plants often borne on 'S' shaped twigs. Die-back of twigs noted. Slits occur on the bark of stems and gum exudes. The condition is called exanthema. Fruits show gum pockets around central pith. Gum exudation can be seen on the rind also. In acute cases, the plants become stunted. Leaves become twisted or malformed. The Cu deficient twigs usually show multiple bud development. They produce a dense, somewhat bushy growth. Quite frequently, copper deficiency results in the appearance of Witchs' broom habit.

Management : Apply copper sulphate @ 500 g/tree as basal + 2 foliar sprays of copper sulphate at 500 g/100 lit of water twice at 30 days interval before flowering.

3. GRAPES

MAGNESIUM : The typical leaf chlorosis is easily recognized at harvest time in heavy bearing vineyards, the leaves towards the ends of the canes being most affected.

Management : Foliar sprays of $MgSO_4$ @ 1 kg / 100 lit of water.

ZINC : The lower portions of the newly planted vine just being trained up exhibit very small incupped leaves called **little leaves**.

Management : Foliar spray of $ZnSO_4$ at 500g / 100 lit of water twice at 15 days interval before flowering.

BORON : Boron deficiency in grapevine commonly reduces the fruit set. Further productions of more number of small and seedless fruits are seen surrounding big berry. This phenomenon of bunches with varying sizes is called **Hen and Chicken.**

Boron deficiency in grape vine commonly reduces fruit set. Further, production of more number of small seedless fruits is seen surrounding big berry. This phenomenon of bunches with varying sizes is called 'hen and chicken'. Such fruits will be sour in taste and naturally weigh less than the fruits from normal vines.

Management : The soil should contain 1 to 2 ppm of water-soluble boron. If the soil contains more than 3 ppm boron toxic level creeps in. About 30g of commercial borax per pit is sufficient to rectify the deficiency. Foliar spraying of borax at 0.25 % (2.5g per litre of water) is also recommended.

4. MANGO

Important physiological disorders due to nutirent deficiencies

NITROGEN : Nitrogen deficiency caused small leaves and general yellowing when N deficiency was very pronounced, fruit size was drastically reduced and tended to ripen and drop prematurely.

Management : Spraying of urea at 4 to 6% during the vegetative stage of crop growth.

ZINC : The symptoms were expressed as formation of little leaf. Zinc deficiency markedly reduced the leaf size and inhibited plant growth appreciably.

Management : Foliar sprays of $ZnSO_4$ @ 0.2 % to 1 % to be applied immediately after noting the symptom.

SOFT NOSE IN MANGO : The interactive effect of nitrogen and calcium in the soil causes this disorder. In acid sandy soil, the incidence is about 7 % only in the trees receiving low levels of nitrogenous fertilizer, while it is increased to 78 % on trees receiving 10 times more of N fertilizer. When leaf calcium content is kept at 2.5% or slightly higher, the incidence of soft nose reduces appreciably.

Remedial measure : Apply calcium nitrate or gypsum or lime stone.

BLACK TIP IN MANGO : In India, mango necrosis or black tip is common.

Symptom : Yellow spots first appear at the distal end of the fruits, which later on turn brown and finally black. This disorders usually occurs in orchards located near the vicinity of brick kilns. The extent of the damage to the fruit is more or less directly proportional to the distance between the orchard and brick kiln. The loss due to black tip is very serious in orchards located within 3 to 4 km from the brick-kiln but during very dry weather conditions (April – May), the damage is more severe and also noticed in the orchards located far away (upto 8 km) from the brick kilns. The fumes that come out the brick kilns as a result of burning of coal contains carbon monoxide, ethylene and sulphur dioxide (SO_2). All these gases are toxic to the young developing fruits of mango but the acidic fumes of SO_2 are the most harmful in accentuating this disorder. There is also interaction between boron content of the plant and fumes of brick kiln causing the disorder.

Remedial measure : This disorder can be minimized by the spray of 0.6 % borax and 0.8 % caustic soda, thrice, i.e. before flowering, during flowering and at the fruit-set stage.

FRUIT DROP IN MANGO : The problem of fruit drop is quite serious in some of the commercial varieties of mango and cause great loss to the growers. The phenomenon of fruit drop in mango in North India has been divided into three distinct phases e.g. pin head drop, post-setting drop and May drop. Fruit drop at the initial stage (first phase) may not affect the yield much, while the same at later stages (second and their phases) drastically reduces the return to the farmers.

Causes of fruit drop : Fruit drop has been attributed to many causes, which include abortion of embryo, degeneration of ovule, depletion of nutrients and hormonal imbalance.

Remedial measure : Fruit drop may be controlled by the sprays of NAA or 2,4 – D at 20 ppm at pea size of the fruit.

5. GUAVA

Fatio Disease in Guava

Symptoms : The affected leaves show red spots, which coalesce and subsequently dry up. The branches develop cracks and finally die-back. Break down of internal tissues of fruits is also noticed in extreme cases. Deficiencies of organic matter, nitrogen, zinc and boron might be the cause for this disorder.

Remedial measure : Application of FYM at 50 kg / tree combined with the foliar spray of 0.5 % $ZnSO_4$ and 0.2 % boric acid would mitigate the disorder.

ZINC : Zinc deficiency caused interveinal chlorosis, reduced size and leatheriness of leaves, reduced plant growth, die – back of branches, production of few or no flowers and drying and cracking of fruits.

Management : Two bimonthly summer sprays of commercial $ZnSO_4$ (0.45 kg $ZnSO_4$ + 319 g lime in 72 / lit of water). Application of $ZnSO_4$ at 300 g / plant and trunk injection at 38.9 g of the pure chemical distributed on all sides of the tree could also alleviate the deficiency.

Growth Ma ipulatio i Yropical 7ruit Crops to Overcome Ehysiological Co strai ts

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The productivity as well as the quality of fruit crops is affected to a greater extent due to the physiological and nutritional disorders. Disturbance in the plant metabolic activities resulting from an excess or deficit of environmental variables like temperature, light, aeration and nutritional imbalance result in crop disorders. In fruit crops, the deficiency of micronutrients causes many more disorders than that of macronutrients. Nutritional disorders have become widespread with diminishing use of organic manures, adoption of high density planting, disease and salt tolerance, unbalanced NPK fertilizer application and extension of horticulture to marginal lands. To get high quality fruits and yields, micronutrient deficiencies have to be detected before visual symptoms are expressed.

The deficiencies of Zn, Mn and B are common in sweet orange, acid lime, banana, guava and papaya in India. To correct both visual and hidden micronutrient deficiencies, appropriate foliar and soil applications are necessary. The description of physiological and nutritional disorders in crops include a number of technical terms and it is essential to understand the terms for better identification of symptoms. Some common terms are bronzing (development of bronze or copper colour on the tissue), chlorosis (loss of chlorophyll resulting in loss of green colour leading to pale yellow tissues), decline (onset of general weakness as indicated by loss of vigour, poor growth and low productivity), die-back (collapse of the growing tip affecting the younger leaves), firing (burning of tissue accompanied with dark brown or reddish brown colour), lesion (a localized wound of the leaf/stem tissue accompanied with loss of normal colour), necrosis (death of tissue), scorching (burning of the tissue accompanied with light brown colour resulting from faulty spray, salt injury etc.)

Some crops are more sensitive than others to the deficiency of a micronutrient and it can be inferred that the critical concentration of a nutrient is not same for all the crops. The susceptibility or tolerance rating of crops to nutrient deficiencies show considerable variation due to wider hereditary variability within a crop species (Tandon, 1995).

Nevertheless apart from these, special problems may arise out of usage of a wrong variety to suit the season and soil, problems posed by characteristics of soil, quality of irrigation water, environment induced problems, toxicity of various kinds and pollution problems. Because of these, the crops exhibit some disorders and some of the characteristic symptoms are

i. Complete crop failure at seedling stage
ii. Severe stunting of plants
iii. Specific leaf symptoms
iv. Internal abnormalities like clogged conductive tissue
v. Abnormal reproductive parts, flowers, fruits etc.
vi. Delayed or abnormal maturity (N & P)
vii. Poor quality of crop

The problems (disorders) caused by different factors in any crop are given below.

a) The selection of a wrong variety for a particular season lead to continuous vegetative growth (ie no flowering occurs)
b) The pH and calcium carbonate content of saline and alkaline soils causes either deficiency or excess of micro nutrients as well as macronutrients result in imbalance.
c) The pH, EC, TSS and boron content of irrigation water cause nutritional disorders in crops.
d) The sudden increase or decrease in temperature causes phosphorus deficiency. Besides, the toxicity problems occurs due to micronutrients and Bordeaux mixture.

Physiological basis of growth manipulation

The size and shape of the canopy may be manipulated through physical (pruning and training) and chemical means.

Physical manipulation

Pruning

Need for pruning

Pruning is a tool to regulate the tree size and shape to achieve a desired architecture of the canopy and also to reduce the foliage density by removing the unproductive branches of a tree. Pruning brings the balance between vegetative and reproductive functions.

Altered physiology

Saidha (1980) observed that, as a result or pruning, the dry matter content in leaf and stem reached the maximum by October – November so that the C/N ratio was the highest during November-December in Neelum, Banglora, Mulgoa and Peter cultivars. This seems to be owing to increased photosynthetic efficiency as a result of improved light penetration in the trees. High C/N ratio, however, did not always govern the fruit bud formation but the accumulation of starch at critical period was of special significance for fruit bud formation.

Ribonucleic Acid (RNA)

As a result of pruning, the RNA content of leaf, which attained the maximum level at the time of flower bud formation, was significantly higher during the second 'normal' year than in the first 'lean' year. The treatments did not affect the RNA content in all the cultivars or in both the years. The RNA content gradually declined after October-November. A higher RNA content at pre-flower bud formation stage and a declining trend with the progress of flower bud formation, were also demonstrated in the mango cultivars Langra and Fazil (Mazumdar and Chatterjee, 1972). Increased RNA contents coinciding with flower bud formation in Mulgoa, Banglora, Neelum and Banganapalli have also been reported (Suryanarayana, 1975).

Ascorbic acid

The treatments of pruning and thinning or thinning alone increased the ascorbic acid content from September onwards with a varying response in different cultivars (Saidha, 1980), however, Suryanarayana (1975) observed that the ascorbic acid content in mango leaves reached a major peak in November coinciding with flower bud formation.

Total phenols

Pruning and thinning or thinning alone increased the total phenolics content as a result of improved light conditions of trees. Phenolic acids have been shown to act as inhibitors similar to abscisic acid to be favourable to flower bud formation in mango (Chacko, 1968). Saidha (1980) also observed that the total phenolics content in the leaves of a flowering shoot was higher than in a vegetative shoot.

IAA-oxidase activity

Lower IAA – oxidase activity was observed as a result of pruning and thinning (Saidha, 1980) which possibly made optimum levels of auxin available to favour flowering. However, higher auxin level at the time of flower bud formation has been reported (Chacko, 1968).

Impact of altered physiology

- Increased yield and fruit quality
- Avoidance of build up of micro climate for the disease and pest.
- Convenience in carrying out the cultural operations.
- Improving access and visibility of fruit during harvest.

Training

Need for training

Training of the perennial trees to the open vase centre is an age old practice to harvest the advantage of the light and ventilation. Basically, the training is a potential tool to manage the canopy architecture of a plant with weak stem like grape vine. Bower system of the training has been found to be the best in tropics throughout the world. Training facilitates channeling its energy distribution from vegetative to reproductive growth.

Altered physiology

Training help to create favorable microclimate so as to manipulate the physiology of vine.

Impact of altered physiology

- Increased productivity and fruit quality
- Gives a desirable shape that maintains its vigour for a long period
- Facilitates requisite leaf exposure and different cultural operations including harvesting and plant protection

- Good protection against hot desiccating winds
- Bunches were saved from damage by birds and sun scorch
- Wood growth is suppressed due to shading effect

Chemical manipulation

Need for chemical manipulation

Plant growth substances are chemicals that are central to plant growth and development. They regulate the rate by which the individual part of a plant grow and integrate growth of those parts to form the whole organism and control reproduction. Plant hormones also allow mature plant to respond to changes in their environment.

Altered physiology

Plant growth substances regulates the cell division, elongation and enlargement. Apical dominance is controlled by cytokinin like substances. Assimilation and translocation can also be increased by growth regulating substances. Root system may be promoted or less impeded and hence shoot / root ratio is lowered.

The effect of fruit thinning on fruit size is related to the leaf / fruit ratio. As this ratio is reduced below 30/1, fruit size is reduced as well.

Impact of altered physiology

- Increased yield and quality of fruits
- Over coming apical dominance
- Early ripening and improved surface colour
- Delayed senescence
- Prevent seediness (Poovan)
- Suppress the excessive vegetative growth
- Prevent abscission

Practical application in overcoming the constraints

Sl.No.	Crop	Nature of work	Outcome	Scientist
1.	Guava L-49	Pruning on 25 years tree. 3 cm pruning of thick shoots from tip Diseased and dried branches were removed from bases	Improved fruit yield and quality	Dalal et al., 2004
2.	Mango Cv. Alphonso	Foliar spray- urea (2&4%)	Improved fruit retention	Bhambid et al., 1988
3.	Mango Cv. Dashehari	Foliar spray - 4% $CaNO_3$ containing 50 mg Boric acid	Improved fruit retention	Anon, 1988
4.	Sweet orange	Foliar spray - 0.5% $ZnSO_4$ + 15 ppm 2, 4-D + BM (2:2.50)	Reduced fruit drop	Gill *et al.,* 1983
5.	Banana Cv. Poovan	Soil application 5 g triacontanol /plant in vermiculate medium at 7, 13, 15 DAP	Increased no. of leaves, hands/ bunch and bunch weight	Nagalakshmi *et al.,* 1989
6.	Pine apple	2 g calcium carbide / plant	Induction of flowering	Singh and Rameswar, 1974
7.	Mango	2, 4-D during flowering (10 ppm) + 1 month after flowering (30 ppm) +2 months after flowering (10 ppm)	Control of fruit drop	Sarma *et al.,* 1981

Sl.No.	Crop	Nature of work	Outcome	Scientist
8.	Ber	Pruning during summer on full grown trees by heading back at 8 buds levels of previous years growth	Higher yield and better quality	Harmail Singh *et al.*, 2004
9.	Mango Cv. Amrapali	Response of air layering to coloured poly wrappers	Red, blue & black poly wrappers significantly influenced the rooting and survival of layers compared with white, green and yellow poly wrappers	Baghel, 1999
10.	Guava Cv. sardar	Spacing trial (6 x 4, 6 x 5, 6 x 6 m^2)	Trees spaced at 6 m^2 intercepted maximum radiation & increased fruit quality	Ajitpal singh and Dhaliwal, 2004
11.	Mango Cv. Cat Hoa Zoc	Soil application of paclobutrazol (5 g / tree) on eighth year	Induction of off-season flowering	Tran *et al.*, 2002
12.	Grapes Cv. venus	Clusters treated with 100 mg GA3 + 20 ppm CPPU	Increased weight of cluster and berry size by 75%	Tao *et al.*, 2001
13.	Mango	Early deblossion combined with NAA spray	Reduce the extend of malformation	Majunder *et al.* 1970

Plant growth regulators used to modify various aspects of *V. vinifera*

Trade name	Chemical name	Class of compound	Effects
4-CPA daminozide (Alar)	4-chlorophenoxyacetic acid Butanedioic acid mono (2.2-dimethylhydrazide)	Auxin Growth retardant	Increase berry size and Increase berry set
Ancymidol	a-cyclopropyl-a[p-methoxy-phenyl]5-pyrimidine methyl alcohol	Growth retardant	Increase the number of surviving embryos in stenospermic cultivars
Chlormequat (Cycocel) Ethephon	2-chloroethyl trimethyl-ammonium chloride 2-Chloroethyl phosphonic acid	Growth retardant Ethylene precursor	Significant increase in berry set Production of viable seed from stenospermic cultivars, increase coloration and sugar percentages in berries, speed maturation
PBA	6-[benzylamino]-9[2-tetrahydro-pyranyl]\9H-purine	Cytokinin	Conversion of tendrils into inflorescences, production of perfect flowers on staminate vines
Phosfon-D	Tributyl-2,4-dichlorobenzyl-phosphonium chloride	Growth retardant	Significant increase in berry set

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Strategies i Weed Ma ageme t i 7ruit Crops

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The diverse soil types and climatic conditions in our country encourage the growth of a broad spectrum of grassy (monocot) and broad leaf (dicot) weeds. All the 18 world's worst weeds are found in India in association with one or the other horticultural crops.

World's worst weeds

S. No.	Name of weed	S. No.	Name of weed
1.	*Cyperus rotundus* L.	10.	*Chenopodium album* L
2.	*Cynodon dactylon* Pers.	11.	*Digitaria sanguinalis* (L) Scop.
3.	*Echinochloa crusgalli* (L) Beauv.	12.	*Convolvulus arvensis* L.
4.	*Echinochola colonum* (L) Link.	13.	*Avena fatua* L.
5.	*Eleusine indica* (L) Gaertn.	14.	*Amaranthus hybridus* L.
6.	*Sorghum halepense* (L) Pers.	15.	*Amaranthus spinosus* L.
7.	*Imperate cylindrica*l (L) Beauv.	16.	*Cyperus esculentus* L.
8.	*Eichhornia crassipes* (Mart.) Solms	17.	*Paspalum conjugatum Berg.*
9.	*Portulaca oleracea* L.	18.	*Rottboelia exaltata* L.f.

Weeds harm the crops and environment in more than one way. Generally, there are two types of weeds, one that emerge before or after the crop emerges and are less competitive and can be controlled easily and the other that emerge simultaneously with the crop and are more difficult to control.

Weeds have peculiar characteristics that help them compete successfully with the crops. They have short life cycles compared to crops in which they occur and complete 3-4 life cycles before the crops come to flowering. They have an inherent capacity to produce innumerable number of seeds armed with good dispersal mechanisms, e.g., *Parthenium hysterophorus* L., *Achyranthes aspera* L. and *Bidens pilosa* L. Some weeds of perennial nature are blessed with vegetative propagation characteristics like underground nuts (*Cyperus* spp.), stolons (*Cynodon dactylon* Pers.) and bulbs (*Oxalis* spp.) that remain dormant in the soil for a long period to tide over adverse climatic conditions.

Similarly, the seeds of *Tephrosia purpurea* and *Trianthema portulacastrum* which are found in arid zones have long dormancy period protected by hard seed coats with improperly developed embryos that help them to overcome the adverse climatic conditions. Weeds have well developed root systems like crops and when they are grown closely with crops, there is competition between overlapping root systems resulting in decreased yield. This is well illustrated in tuber crops like potato, sweet potato and tapioca and in vegetable crops like cabbage, cauliflower, beet root, carrot, radish, onion and garlic. Weeds compete successfully with crops for water, mineral nutrients, light, space, etc., besides harboring dangerous pests and diseases. In non-irrigated areas, the competition between weeds and crops is largely for water. The competition for light is an important component of total competition that restricts crop yields. Weeds usually absorb fertilizers faster than crops and therefore derive greater benefit.

The yield loss due to unchecked weeds varies from 34.0 to 71.7 per cent in fruit crops, 10-95 per cent in vegetables, and 25-80 per cent in tuber crops.

Weed control represents a major cost item in horticultural crop production and has now become a part of modern agricultural technology. For centuries, man fought weeds with his hands, hoes, animal power cultivator and mechanical power. Recently, chemical control using herbicides has assumed great significance and is being adopted all over the world effectively.

More weeds in orchards?

- Crops are widely spaced
- Mostly irrigated
- Highly fertilized
- Open crop canopy
- Perennials

Weed control methods

Commercial growers usually aim at two types of weed control, one, where weeds are reduced and another, where weeds are completely eradicated. Owing to its difficulty and higher cost, eradication is attempted in relatively small areas, e.g., nursery areas. Different methods of weed control are discussed below.

Preventive weed control

Preventive weed control is concerned with measures taken to prevent the introduction, establishment and or spread of specified weed species in areas not currently infested with these plant species. In foreign countries, strict laws are enforced so that noxious weeds are not carried from one region to another, but in India, such laws do not exist. With the result, *Parthenium hysterophorus*, a noxious weed, has been carried far and wide throughout the country by various means posing a national problem. Preventive methods of weed control include weed free crop seed, weed free manure, clean (weed free) harvesting equipment and ploughing implements and elimination of weed infestations in and around irrigation waters and cultivated fields.

The following are some weed control methods followed in orchards.

I. Cultural Method of Weed Control

Any weed management programme on farmland essentially begins with adoption of good crop husbandry practices leading to a sturdy crop which could overpower the weeds and make their subsequent control easy and more economical. Some important good crop husbandry practices which can bring about effective suppression of weeds in farming systems are as follows.

1. Proper crop stand

Gapy and under population crops are prone to heavy weed infestations which become difficult to control later. Therefore, practices like selection of proper seed, right method of sowing, adequate seed rate, protection of seed from soil borne pests and diseases, etc., are very important to obtain proper and uniform crop stand capable of offering initial competition to the young weeds.

2. Selective crop stimulation

Basal placement of fertilizers in the seed rows often helps in selectively stimulating the crop seedlings which can withstand competition from the weeds much better. The various plant protection measures adopted to maintain the crop plants healthy should be considered as part of good crop husbandry leading to effective weed management.

If the soil was of abnormal pH, not suited much to the crop, use of proper soil amendment should be considered necessary to boost crop growth and thus, indirectly suppress the weeds.

3. Crop rotation

Many of our weed problems exist with us because of practising monocultures i.e. growing of same crop year after in the same field. Parasitic weeds, as well as the crop associated weeds, can be discouraged by adopting well conceived crop rotations.

4. Summer tillage

There is a clear cut solar energy-rich, dry period of summer available, which should be utilized for desiccation of rhizomes, tubers and roots of the perennial weeds to death.

5. Solarisation

In this method the soil temperature is further raised by 5-10°C by covering a pre-soaked fallow field with thin, transparent plastic sheet. The plastic sheet checks the long wave back radiation from the soil and also prevents loss of energy by hindering moisture evaporation.

6. Reduction in area under bunds and channels

Weeds grow profusely on bunds and channels of crop fields. Also, these weeds are often ignored by the farmers since they don't compete directly with crop plants.

7. Stale seed bed

A stale seed bed is one where initial 1-2 flushes of the weeds are destroyed before planting of a crop. This is achieved by soaking a well prepared field with either irrigation or rain and allowing the weeds to germinate. At this stage a shallow tillage or a non-residual herbicide like paraquat may be used to destroy the dense flush of young weed seedlings. This may be followed immediately by sowing desired crop. The technique allows the crop to germinate in almost a weed-free environment.

8. Mulching

Black plastic mulches of about 1000 gauge thickness have proved very useful in suppressing weeds and conserving soil moisture at the same time.

The use of plastics in agriculture for different purposes, including for mulching, has been named plasticulture.

9. Inter-cropping

Inter-cropping helps in the suppression of atleast the secondary growth of weeds that occurs after the inter-crop has fully covered the ground. Cowpea, groundnut, redgram, blackgram and greengram are common inter-crops in India used to increase the total crop productivity and suppress the secondary growth of weeds.

A fast shading inter-crop is also known as smother crop.

II. Mechanical Weed Control

In the method of mechanical weed control, various tools and implements are used. They are as follows:

1. Hand hoe

Hand hoeing is the most common mechanical method of weed control in India. The shape and size of the hoe varies from place to place. Hoeing loosens the soil surface and produces mulch.

2. Spade

Spade is shaped like a hand hoe but bigger in size. Digging can be done in between the crop inter row space with spade. Wherever wider row space is available, spade is used instead of hand hoe. Depending on the regions, the shape and size of the blade varies.

3. Country plough

It is used for opening the soil, removal of weeds, preparing seed bed and also covers the manure spread on the land.

4. Crow bar

It is a long iron rod of 4-6 feet height with one end sharpened and used to uproot the deep-rooted weeds like *Solanum elaegnifolium.*

5. Scythe (Swinging sword)

It is used to cut the above ground part, which are normally grown in non-cropped areas like around the building sites and along the road sides.

6. Junior hoe

It is a bullock drawn cultivator generally used in South India for inter-cultivation in crops like sugarcane and cotton and in orchards. It is a light implement primarily designed for loosening the soil and controlling the weeds between the crop rows, which are wide spaced.

7. Blade harrow

It is a bullock drawn row cultivation implement. Its cutting tool is a sharp blade, which works almost like sweep of a cultivator. It cuts the weed below the ground and leaves them on soil surface as mulch without causing inversion of the soil. It is the common row-weeding implement on heavy black soils in India. This is locally called as 'Guntaka'.

8. Long handled rotary weeders

a. Japanese rotary weeder

This is one of the labour saving hand operated implement which can be used in wetlands.

b. Peg type weeder

It is a manually operated push-pull type single row weeder. It is suitable for interculture and weeding operations in black cotton soils.

c. Star type weeder

It is a manual push-pull type weeder suitable for weeding in row crops in rainfed as well as garden lands.

III. Chemical Weed Control

Chemical weed killing was born in 1896 when Bonnet, a French grape grower, observed that the Bordeaux mixture which he used against downy mildew of grape turned the leaves of *Sinapis arvensis* (a weed) black later, the weed killing properties of sulphates of ammonia, zinc, iron and other metals were soon observed. Further milestones in weed control were introduction of organic chemical, 2-methyl-4, 6-dinitrophenol (DMOC) in 1932 and discovery of hormone type selective weed killers. Selective residual chemicals such as substituted phenyl ureas and triazines and non residual chemicals diquat and paraquat are more recent discoveries.

Weed control through herbicides

A herbicide is a chemical used to kill some target plants. In agriculture these target plants are weeds. Thus, when we talk of herbicides, we mean chemical warfare against weeds to the extent of killing or severely stunting these, depending upon our objective.

Advantages and limitation of herbicides

The major objective of discovering and using herbicides has been to replace the torturous, back breaking, manual weeding and let the farmer use his time thus spared in some other farming operations. The farm children need to go to school instead of wasting their lives in weeding. Even rising wages and fuel costs have also given impetus to the farmers to switch over to herbicides to control weeds, at least in part. Besides such reasons, there are some additional **benefits that accrue** frequently from the use of herbicides in agriculture as follows.

i. Herbicides can control weeds even before they emerge from the soil so that crops can germinate and grow in completely weed free environment during their tender, seedling stage. This is usually not possible with the physical weed control procedures.

ii. In broadcast sown and narrow row crops herbicides prove very effective in controlling each and every weed. Mechanical weeding methods cannot be employed in such crops.

iii. In wide row crops although inter cultivation is very commonly practiced to remove the inter row weeds, but it leaves the intra row weeds unhurt. Herbicides reach both inter row and intra row weeds equally well.

iv. There are certain weeds which resemble during their vegetative phase like crop plants with which they are associated. Such weeds therefore escape the farmer's hoe. But now herbicides are available which can distinguish between such weeds from the crop plants and control them easily, without any damage to the crop

v. In the event of incessant rainfall, there is no opportunity for the farmer to use his hoe even though the weeds may be growing by leaps and bounds. Early application of herbicides at the time of sowing can allow the young crops to grow in a weed free environment.

vi. Herbicides withhold the weeds for considerable period after their application. This is in variance with physically uprooted weeds which tend to grow back soon.

Probably one could think of some more advantages of using herbicides in agriculture. But at the same time one should be familiar with certain important limitations of introducing herbicides, particularly in the developing countries. These **limitations are as follows.**

i. The use of herbicides requires some technical know-how on the part of the farmer in respect of the choice of particular herbicides, their appropriate time and method of application and precautions required in their storage and use. The success of a herbicide is greatly dependent on the soil type, crop and its variety to be treated, weed flora present and the prevailing environmental conditions. A farmer must understand these implications well before introducing any herbicide in his farm.

ii. Over and under dosing of herbicides can make a marked difference between the success and failure of obtaining selective weed control.

iii. Certain herbicides, because of their long term residues in soil may impose limitations on the choice of crop rotations on the farm.

iv. Herbicide drifts to crop growing in the neighbourhood can invite unhealthy quarrels.

Adjuvants

Adjuvants are chemicals that improve the herbicidal effects, without being phytotoxic by themselves.

Following are the common kinds of adjuvants used with herbicides.

Wetting agents

Some weed foliage may not get wet by aqueous herbicide sprays, (eg. bermuda grass (*Cynodon dactylon*). When a wetting agent is added to the spray tank, the spray immediately wets the foliage and the herbicide action becomes rapid. In many commercial herbicide formulations the wetting agents are already provided. The wetting agents are also called surfactants or surface active agents. Even soap solution acts as a

Herbicide recommendation for fruit crops

Crop	Herbicide chemical name	Active ingredient kg ai/ha	Commercial name	Dose kg/ha	Time of applicaiton
Mango	Diuron	2.0	Karmex 80 wp Hexuron 80 wp Diuron 50 wp	2.5 2.5 4.0	Pre
	Atrazine	2.0	Atrataf 50 wp	4.0	Pre
	Paraquate	*2.0*	Gramaxone 20ec	*10*	Post
Banana	Alachlor	2.0	Lasso 50 ec	4.0	
	Diuron	2.0	Karmex 80 wp Hexuron 80 wp Diuron 50 wp	2.5 2.5 4.0	Pre
	Oxyfluorfen	1.0	Goal 24 ec	4.0	Pre
	Paraquat	2.0	Gramaxone 20 ec	10	Post
	Glyphosate	3.0	Glycel 41 SL Round up 41 SL	7.0 7.0	Post
	2,4-D sodium	3.0	Fernoxone		Post
Grapes	Atrazine	2.0	Atrataf 50 wp	4.0	Pre
	Diuron	2.0	Karmex 80 wp Hexuron 80 wp Diuron 50 wp	2.5 2.5 4.0	Pre
	Oxyfluorfen	1.0	Goal 24 ec	4.0	Pre
	Paraquat	2.0	Gramaxone 20 ec	10	Post
	Glyphosate	3.0	Glycel 41 sl Round up 41 sl	7.0 7.0	Post Post
Papaya	Fluchloralin	2.0	Basalin 48 ec	4.0	PPI
	Alachlor	2.0	Lasso 50 ec	4.0	Pre
	Butachlor	2.0	Machete 50 ec	4.0	Pre
	Diuron	2.0	Karmex 80 wp	2.5	Pre
			Hexuron 80 wp	2.5	Pre
			Diuron 50 wp	4.0	Pre
Citrus & Sapota	Diuron	2.0	Karmex 80 wp Hexuron 80 wp Diuron 50 wp	2.5 2.5 4.0	Pre Pre Pre

wetting agent, although more potent wetting agents like Uphar, Teepol etc., suited to different kinds of herbicides are marketed in India.

Drift control agents

Herbicide spray drifts may pose serious hazard to the non target plants in the neighbourhood. Adjuvants are available that reduce the spray drift possibilities by either (i) Increasing the droplet size, (ii) Forming a foam, or (iii) Making invert emulsion. Drift control agents are particularly necessary in aerial application of herbicides.

Herbicide rotations and combinations

The persistent use of a herbicide in a field year after year has been documented to gradually bring about a change in weed flora and the new weeds are often more hardy than the original ones. The phenomenon has been named as ecological shift in weed flora. Many examples of ecological shifts in response to repeated use of 2, 4-D have been recorded in India.

To obviate such undesirable ecological shifts in weed flora occurring due to the use of mono herbicides, it is now recommended to adopt herbicide rotations and herbicide combinations. In herbicide rotations, two or more herbicides are selected for a crop situation and these are used in alternate years, just like we practice crop rotations in a field.

Biological weed control

The method involves utilization of natural enemies for the control of certain weeds. The aim is to reduce weed population below the level of economic injury (Anderson, 1977), i.e. to a level non injurious to man's interest. This can be achieved via direct or indirect action of the biotic agents. The principal biotic agents used for control of terrestrial plants has been phytophagous (plant- eating) insects. Herbivorous fish has been the principal agent for biological control of aquatic weeds. Other biotic agents are microorganisms, competitive and parasitic higher plants, sheep, goats, geese, snails, birds and the non herbivorous mud carp.

Insects

Biological weed control poses serious hazards to agriculture and there is no absolute guarantee of safety (Anderson, 1977). Thus, one must be very careful in evolving such a biotic agent which successfully attacks the target weed without harming the other plants, especially the plants useful to man. Control of obnoxious weeds like prickly pear cactus (*Opuntia inermis* D.C) and spiny prickly pear (*Opuntia stricta*) by *Cactoblastis cactorum* Berg, *Hypericum perforatum* L. by leaf feeding beetle, *Chrysolina quadrigemina* (Saffr.), *Parthenium hysterophorus* L. by *Zygograma bicolorata*, water hyacinth (*Eichhornia crassipes* (Mart) Solms.), Nitella and Najas by herbivorous fish, *Tilapia* spp. *Salvinia molesta* by leaf feeding species of grass hopper, *Paulinia acuminate* are examples of biotical weed control.

Allelopathy

Inter weed competition determined by allelopathy can be manipulated to our advantage in the natural control of weeds. Natural compounds released by some plants inhibit or prevent the growth of nearby plants. Known as allelopathic substances, they may be released from roots, leaves or other plant parts. Black walnut trees, for example, inhibit the growth of certain plants near them and thistles exude a substance that interferes with the growth of oats (Sanders, 1981). Such natural herbicides or bioherbicides might reduce, to a great extent, our dependence on synthetic herbicides whose costs are skyrocketing day by day. At the same time, the possibility of incorporating some of these allelopathic compounds into synthetic herbicides during their manufacture may be tried to increases the efficiency of herbicides.

Plant pathogens (Bioherbicidal control of weeds)

Use of plant pathogens, especially fungi, to control weeds 'myco herbicides' is gaining importance in recent years. Improved the potential for weed control using foliar pathogens by applying spores of *Alternaria macrospora* pre emergence in granular formulation so that biocontrol agents are present when weed seedlings of *Anoda cristata* emerge. This technique holds promise because reduced quantities of spores are needed when seedlings are small and emerging. Also, granular formulations can be applied on a band over the crop drill which further reduced the quality of spores needed per unit land area.

This bioherbicide approach involves spray of specific fungal spores or its fermentation products, against the target weed. These preparations are called **mycoherbicides.**

Conclusion

Adequate and timely suppression of weeds is essential to harness full potential of a given genotype

Some commercial mycoherbicides in use abroad

S. No.	Product	Content	Weed controlled
1.	De-Vine	A liquid suspension of fungal spores of *Phytophthora palmivora.* It causes root rot in the weed.	Strangle vine (*Morrenia odorata)* in citrus orchards
2.	Collego	Wettable powder containing fungal spores of *Colletotrichum gloeosporoides* sp. *Aeschynomone*	Joint -ventch (*Aeschynomone* sp.). The bioherbicide causes stem and leaf blight in the weed.
3.	Bipolaris	A suspension of fungal spores. *Bipolaris sorghicola*	*Sorghum halepense* (Johnsongrass)
5.	Biolophos	A microbial toxin produced as fermentation product of *Streptomyces hygroscopicus*	Non-specific, general vegetataion.

of any economic plant species, as well as of the various modern inputs that go into its production. The weedy, as well as untimely weeded agricultural fields, horticultural gardens, grasslands and plantations are unproductive and uneconomical.

Weed management is no more simply a manual, back breaking job. It is now planned as scientifically as the crop management itself, based on certain ecological principles of plant community and good crop husbandry procedures, including the prevention of weeds. Other methods of weed control involving the use of physical, chemical and biotic stresses on weeds are suitably combined with these.

In recent years several herbicides have been made available to deal with the weeds in varied situations, both before and after their appearance on the ground. Many of these are so selective that they prove superior to the human eye in distinguishing between the similar looking weed and crop plants. However, their judicial use requires an insight into their selective behaviour, their residual effects in soils and different non-target organisms and the required precautions essential in their safe use. Further, in any kind of agricultural field the use of herbicide is to be considered as supplement to the other options available for weed management, rather than as means to replace these, particularly in the developing nations.

1 tegrated Eest Ma ageme t i 7ruit Crops

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The advent of green revolution and the associated developments have made the country self sufficient and tremendous progress has been achieved in the production of pulses, oilseeds, fruits, vegetables, plantation and ornamental crops. However, the post green revolution era has witnessed many problems in the field of plant protection.

Indiscriminate use of pesticides have led to many problems in soil, water, air, food and fodder, biomagnifications in food chain, phytotoxicity to plants, adverse effect on non-target organisms, development of resistance in plants to pesticides and induction of resurgence of target and non target pests. Indiscriminate use of pesticides have led to resurgence of sucking pests like leaf hoppers, white flies, mites, etc., besides, the pests like *Helicoverpa armigera* in various crops and pink mealy bug *Maconellicoccus hirsutus* on grapes are difficult to control even with repeated pesticide application. All these ill effects necessitated a need for an alternative eco-friendly pest management with the use of resistant varieties, biocontrol agents, cultural, mechanical and physical methods, behaviour modifying chemicals, botanicals, maintenance of field and plant sanitation, etc., in order to minimise the target pests and to increase the yield both qualitatively and quantitatively.

1. Growing resistant crop varieties

The resistant variety itself forms a major management. The resistance may be non preference , antibiosis or tolerance.

i) The first record of the use of host plant resistance in fruit crops appeared in the United Kingdom when Lindly (1831) recommended an apple variety 'Winter Majetin' to be resistant to the wooly apple aphid, *Eriosoma lanigerum* (Hausm) and is still known to retain its resistance. The most dramatic early success in plant resistance, however, was the control of the grape *Phylloxera*, *Daktulosphaira* (= *Phylloxera) vitifoliae* (Fitch) in European grapevines. Balachowsky (1951) described the brutal appearance of this North American pest species in France in 1861 and its spread to the vineyards of European and Mediteranean countries. The North American pest was inadvertantly introduced into French vineyards in 1861. The American grape species of grapes were highly resistant to the grape phylloxera. The pest rapidly spread to other French vineyards and also other European and Mediterranean countries. The effect was catastrophic and the entire French wine industry was on the brink of collapse by 1880. Then C.V. Riley noted that the North American varieties were resistant to Grape phylloxera. He recommended grafting of North American rootstocks with susceptible European grapevine scions. This produced resistant variety and the French vineyards were reconstituted using these grafts. By 1890, complete control of the pest was achieved. The entire operation cost in France - 10 billion francs, but the French wine industry was saved. Application of such HPR persists to day in the wine producing districts of Western Europe. C.V. Riley was awarded gold medal for making this recommendations.

ii) Against apple wooly aphid, the resistant variety is employed as rootstalk for grafting purpose. Nothern Spy variety resistant to wooly aphis is grafted with susceptible cultivated varieties. Malling-Merton-9 rootstock is being used in Himachal Pradesh owing to its inherent resistance to woolly apple aphid, *Eriosoma lanigerum* (Anonymous, 1978). Some degree of resistance was observed in Golden Delicious to this pest, in Kulu. The resistant variety is employed as rootstock for grafting purpose against apple wooly aphid. The variety Northern spy, resistant to wooly aphid is grafted with susceptible cultivated varieties. Some of the tolerant / resistant varieties to wooly aphid are M 778, M 779, MM 104, MM 110, MM 112, MM 113, MM 114 and MM 115. The resistance characteristics of the apple resistance genes (Er1, Er2 and Er3) to the wooly apple aphid were studied according to the performance measured on apple cultivars containing these resistance genes (Sandanayaka *et al*., 2003). The resistance characteristics of Northern Spy (Er1), Robusta 5 (Er2), and Aotea (Er3) were compared to the susceptible cultivar Royal Gala, by measuring the aphid settlement, development and survival rates correlated with electronically monitored probing behaviour. The results showed that Er1 and Er2 had a higher level of resistance with a significantly shorter period of phloem feeding, suggesting that the resistance factors were present in the phloem tissue. Phenological measurements indicated that the aphids showed poor settlement, development and survival on Er2. Er1 also showed low settlement and survival, although not as low as Er2.

iii) In pomegranate, Karuppuchamy (1995) screened 12 pomagranate cultivars for resistance to pomegranate fruit borer *Dendorix isocrates.* The cultivar Jyothi recorded the lowest fruit damage (6.5%), followed by Bedano Bosco (10.30%) while the maximum fruit damage was observed in the cultivar Coimbatore (30.40%). Ganesh and Yercaud 1 recorded 23.80 and 18.20% fruit damage respectively. There was a negative correlation between fruit damage and rind thickness of the fruit. The rind thickness of Jyothi is 3.58 mm whereas the rind thickness of Ganesh and Yercaud-1 was 2.15 and 2.19 mm respectively.

The biochemical analysis of the flowers and fruits showed that there were negative correlations between fruit damage and phenol and tannin contents in fruits. The resistant varieties Jyothi and Bedano Bosco registered a higher tannin content (6.70 and 6.92 g/100g) and total phenolics (8.03 and 8.20g/100g) as compared to the susceptible variety ‘Coimbatore’ (4.88 and 5.47g/100g of tannin and phenol respectively).

2. Cultural, mechanical and physical methods

- Regular removal of weeds, grasses and alternate hosts minimise pest incidence. Destruction of weed host, *Tinospora* and *Cocculus* controls fruit sucking moths.
- In citrus, management of fruit sucking moths by cultural means like removal of wild creepers of menispermaceae, avoiding fruiting in rainy season, destruction of fallen and decayed fruits which form powerful factor of attraction mechanical methods like smoking, fruit bagging, collection of moths at evening by hand nets, collection of semiloopers from the weeds and creepers and destruction, attraction of moths to strong light and destruction in kerosenised water below such light were advocated (Yadav,1969; Butani,1979).Catching and killing of moths with the help of flame at 8-10 pm was found to be effective for killing *Othreis* sp in pomegranate garden(Mote *et al* ., 1992). Collection and destruction of affected and fallen fruits in mango, citrus, guava minimise the incidence of fruitfly. Ploughing the interspaces during summer expose the puparia of fruit fly in many fruit crops.
- Removal of weeds like *Clerodendrum infortunatum* and grasses by ploughing during November minimise mealy bug in mango.
- Avoiding close plantation, water logging or other stress conditions can reduce the incidence of citrus white and black fly (Batra and Sharma, 2001). Clipping off the affected shoots can reduce the localized infestation and excessive irrigation and nitrogen may be avoided.
- Clipping of dried branches 4 cm below the dried portion prevent further multiplication of stem borer, *Chelidonium argentatum* and scale insects in citrus.
- Banding of trees with 20 cm wide alkathene or polythene (400 guage) in the middle of December 2 - 3 ft above the ground level and just below the junction of branching reduce mealybug incidence in mango. Apply a little mud or fruit tree grease on the lower edge of the band after tying with jute thread to stick to the stem and ensure that the mealy bugs may not climb the tree beneath the band.
- Bagging of pomegranate fruits with polythene bags or butter paper cover or muslin cloth impregnated with malathion 0.1% prevent the egg laying by *Deudorix isocrates.* (Karuppuchamy and Balasubramanian, 2001).

3. Use of bait traps and bait spray

i. Methyl Eugenol trap @ 25/ha is used to attract male fruit flies in mango, citrus, guava, pomegranate, etc. Use bait trap with 100 ml of 0.1% methyl Eugenol (1 ml/lit.) and 0.05% malathion in 250 ml capacity wide mouthed container fitted with hanging device at its neck during March - July in mango and August - March in mandarin orange.

ii. Use of fish meal trap @ 20/acre is highly effective for the attraction of fruitfly and comparatively very cheap (Karuppuchamy *et al*., 1995)

iii. Bait spray with malathion (1 ml/lit.) or carbaryl (4 g/lit.) or dimethoate (1 ml/lit.) in combination with molasses or jaggery (10 g/lit. of water) should be given twice at fortnightly intervals before ripening of fruits for the control of fruit fly.

iv. Poison baiting with fermented molasses + malathion 0.05% is effective against the adults of fruit sucking moth in citrus orchards. Poison baiting with 1% acephate, 1% malathion or 0.5% triazophos and jaggery controls the fruitsucking moth *Achoea janata* in pomegranate (Mote *et al*., 1992).

4. Attracting / repelling adult insects

The adults may either be attracted and killed or repelled to prevent feeding or oviposition.

i. Apply smoke to prevent fruit sucking moth attack in orange orchards.

ii. Collect adult moths with light traps or by keeping pieces of fruits near tree basin to attract sluggish moths in the evening.

iii. Trapping of adult rhizome weevil in banana with pseudostem chopped into pieces. Disc on stump trap and pseudostem split traps are used for trapping both rhizome borer and pseudostem borer of banana. Among these two traps, the disc on trap is more effective which trapped 1014 weevils while the pseudostem splits trapped 437 weevils/week (Padmanaban *et al.,* 2001).

iv. Spraying ovipositional deterrent *viz.*, Neem oil 3% or Neem seed kernel extract 5% immediately after noticing the butterfly activity reduced the oviposition by *Deudorix isocrates* in pomegranate (Karuppuchamy and Balasubramanian, 2001).

5. Biological control

Biological control using insect pathogens, parasitoids, predators is ecofriendly without any harmful effect on human beings.

a. Parasites

Inundative release of *Trichogramma chilonis* @ 15 cc/ha at fortnightly intervals four times starting from flowering reduced the incidence of pomegranate fruit borer *Deudorix isocrates*(Karuppuchamy and Balasubramanian, 2001). On apple, release of *Encarsia perniciosi* or *Aphytis* sp. nr. *Proclia* @ 2000/ infested tree and *Chilocorus infernalis* @ 20/ infested tree against San Jose Scale *Quadraspidiptus perniciosus,* the chalcid parasitoid *Aphelinus mali* successfully checked the aerial forms of apple wooly aphid *Eriosoma lanigerum, Trichogramma embryophagum* at 2000/tree during the active egg laying period of codling moth *Cydia pomonella* had given satisfactory control (Singh, 2001).

b. Predators

The green lace wing *Chrysoperla carnea* has been demonstrated as an effective predator against certain aphids, thrips and mites. *Menochilus sexmaculatus* was found to be an important mortality factor for several species of aphids. *Scymnus coccivora* is found to be an effective predator of both white tailed mealy bug and aphid *Aphis punicae* in pomegranate (Karuppuchamy *et al.,* 1999). Release of coccinellid beetle, *Cryptolaemus montrouzieri* @ 10/grape vine plant successfully controlled the mealy bug. This is also effective against mealybugs in citrus, mango, guava and sapota apart from controlling scales and whitefly (Table 1).

Table 1. Requirement of Australian lady bird beetle for the management of pests of fruit crops

Crop	Pest	Requirement of predator
Mango	*Drosica mangiferae*	50 beetles/tree
Citrus	*Planococcus* spp	10 beetles/tree
Guava	Mealy bug, White fly	10-20 beetles/tree
Sapota	Scale insect	10 beetles/tree
Pomegranate	Scale insect	10 beetles/tree

The coccinellid predators *Chilomenus bijugus* and *Coccinella septumpunctata* control the aerial forms of apple wooly aphid. The two spotted mite *Tetranychus urticae* and European red mite *Panonychus ulmi* were preyed by *Stethorus* sp., anthocorids, chrysopids, predatory thrips and predatory mites (Anon,2000). Weekly release of 7.9 lakhs of *Phytoseiulus persimillis* controlled two spotted spider mite *T.urticae* on stawberry which increased the fruit yield by 7.4 per cent in released plot. *Typhlodromus cucumeris* and *T. reticulatus* were used for the control of cyclamin mite, *Steneotarsonemus pallidus* on strawberry. *T. occidentalis* was successfully used in apple orchards for the control of spider mites. *Amblyseius deleoni* when used @ 1000 mites/tree controlled citrus red mite *Panonychus ulmi* in China.

Release of Laboratory reared colonies of the indigenous obligate predatory mite, *A. longispinosus* has been found to be effective in controlling *T. urticae* on roses (Mallik *et. al*, 1998). The predatory potential of *A. tetranychivorus* against *T. urticae* under both laboratory and polyhouse conditions was demonstrated by Ghosh *et al.* (2000). The prey consumption rate of some of the predators is given in the table 2.

Table 2. Some reported rates of prey consumption of predatory mites under laboratory condition

Species	Prey	Consumption	
		male/day	female/day
Amblyseius tetranychivorus	*Tetranychus ludeni*	9.53 (all stages)	26.74 (all stages)
A.altoniae	*Eutetranychus orientalis*	Larva 2-5 Protonymph 2-7 Deutonymph 5-8 Adult 5-15	-
A.channabasavanni	*Raoiella indica*	Egg 1-42 Adult 6-13	16.5 to 26.3

c. Viruses

The baculoviruses including Nuclear polyhedrosis virus (NPVs) and granulosis virus (GVs) are the most successful groups of pathogens to insect pest suppression and are safer to human, invertebrate and higher animals. NPVs have been effectively used on *H. armigera* and *S. litura*. The successful development of techniques for mass production and field use of NPVs of *H. armigera* and *S. litura* have been well demonstrated in farmers field for pest suppression. Application of four sprays of granulosis virus @ 8 x 10^7 virus capsules/ml at fortnightly interval during active larval stage gave good results against codling moth *Cydia pomonella* in apple (Singh, 2001).

d. Bacteria

The crystelliferous, spore forming bacterial pathogen, *Bacillus thuringiensis* has been studied extensively and found to be effective against several species of lepidopterous pests.

e. Fungi

Easwaramoorthy and Jayaraj (1978), utilized *Verticillium lecanii* effectively to control the coffee green bug, *Coccus viridis* on the lower Palani Hills. The fungus *Noumerae reilyi* is used for the control of various lepidopteran pests. Three rounds of sprays with Bt 0.05% at 15 days interval starting in second fortnight of March effectively controlled bud boring insects such as *Anarsia achrasella* and *Nephopteryx eugraphella* (Patel, 2001).

6. Use of botanicals

Botanical pest control is becoming relevant not only to developing countries with limited options for other control measures, but also attracting attention in developed countries which, although food sufficient, are increasingly becoming conscious of food safety. Grainge and Ahmed (1988) listed about 2400 plant species with pesticidal properties (insecticide, acaricide, nematicide, fungicide etc., which are distributed in 189 plant families)

Spraying neem oil 3% or Neem seed kernal extract 5% is effective against a wide range of pests in fruit crops. It is also effective against aphid *Aphis punicae* in pomegranate (Karuppuchamy *et al.*, 1998) and anar butterfly *Deudorix isocrates* in pomegranate (Karuppuchamy and Balasubramanian, 2001).

7. Pheromones

A pheromone is a chemical or mixture of chemicals released by an organism to the outside (in the environment) that cause a specific reaction in a receiving organism of the same species. Pheromones are species specific and their safety to beneficial organisms makes them ideal components of integrated pest management systems. Of the various pheromones, the sex and alarm pheromones are used for pest management in India. Sex pheromones help in mass trapping and mating disruption of insects.

8. Chemical control

In the absence of eco friendly pest control agents, farmers are forced to use chemical insecticides. A sensible and need based use of pesticides can significantly reduce their harmful effects on the environment.

9. Conclusion

By properly integrating all these non-chemical methods, insect pest on different crops can be managed in a sustainable manner without causing any ill-effects to human beings, non-target beneficial arthropods as well as the environment. With the growing demands for organically cultivated agricultural products, these eco friendly management strategies will find greater application in the coming century.

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1mporta t Diseases o(Ba a a a d Eapaya a d their Ma ageme t

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Diseases and pests are increasingly limiting factors in small holder and export production and can cause catastrophic losses in banana (Jones 2000). *Musa* diseases and pests are significant problems worldwide. Diseases affect all portions of the plants, are caused by fungi, bacteria and viruses and have been the subjects of entire books (Jones 2000, Stover, 1972 ; Wardlaw, 1961).

Fungal Diseases

Diseases that are caused by fungi are most common and destructive (Jones, 2000).

Panama wilt disease *: Fusarium oxysporum* f. sp. *cubense.*

Fusarium wilt is a lethal and widespread problem on this crop (Pletz and Pegg, 2000). It devastated the export trade that depended on Gros Michel (AAA) until 1960. A recently recognized variant, tropical race 4 (TR 4), affects Cavendish cultivars and threatens export and smallholder production of it and many other cultivars outside its endemic, Southern Asian range.

Symptoms

The symptoms appear as yellowing of the lower most leaves. Yellowing extends upwards and finally heart leaf alone remain green. The leaves break near the base and hang down around pseudostem. Longitudinal splitting of pseudostem can be in advanced stages. Discolouration of conducting vessels due to the presence of reddish brown radiating mycelial strands which can be seen when the corm is cut open. The fungus survives in soil as chlamydospores for longer periods. The fungus also spread through irrigation water. Continuous cultivation results in build up of inoculum. Variety Poovan shows resistance, Rasthali and monthan susceptible to the disease.

Management

i) Paring and pralinage of suckers using carbofuron @ 40 g / sucker at the time of planting. ii)Capsule application of carbendazim @ 40 mg/capsule/tree on 3, 5 and 7^{th} month after planting. iii) The capsule is applied in the corm by making a hole at 45° of 10 cm depth (or) Adopt corm injection 3 ml of 2% carbendazim injected by making hole at 45°as mentioned earlier. iv) Flooding the infected fields (or) raise paddy crop for one season to suppress the pathogen. V) Raising sunhemp or marigold as intercrop and after a month ,they are ploughed *insitu* to reduce the nematode population.

Sigatoka leaf spot : *Cercospora musae (Mycosphaerella musicola)*

Leaf spot diseases caused by species of *Mycospherella* result in moderate to severe damage wherever significant rainfall occurs (Jacome *et al*., 2003). Black leaf streak disease better known as black Sigatoka and caused by *Mycosphaerella fijiensis*, is most important. It occurs throughout the humid, lowland tropics and has a wide host range that includes the Cavendish sub group (AAA) and plantains (AAB). In some areas, eumusae leaf spot caused by *Mycosphaerella eumusae*, Sigatoka caused by *Mycosphaerella musicola* and speckle caused by *M. musae* are equally or more important.

Symptoms

The fungus causes elliptical, sharply defined lesions which is especially obvious on necrotic tissues. The leaf dries upon severe infection and reduces the yield considerably. The fruits from the affected plant tend to ripen prematurely and may show peel splitting that reduces the value of the fruit in the market.

The fungus survives in the infected banana leaves. Secondary infection is by the windborne conidia of the fungus.

Key for assessing the infection grade (Gauhl *et al*. 1993)

0 = No symptoms, 1 = 1% of lamina with symptoms, 2= 1 to 5% of lamina with symptoms, 3= 6 to 15 %, 4 = 16 to 33 %, 5 = 34 to 50 % and 6= 51 to 100 % of lamina with symptoms.

$$\text{Infection index} = \frac{\Sigma nb}{(N-1)\,T} \times 100$$

Where n = number of leaves in each grade, b= grade, N= Number of grades used in the scale (7), T = Total number of leaves scored.

Management

Kannan *et al.* (2004) reported that application of 0.1% propiconazole (Tilt 25 %EC) and 0.1 % Thiophanate methyl (Topsin M) were found to be effective and on par with 0.1 % carbendazim in reducing the intensity of Sigatoka leaf spot disease. Yield increase over control was also observed maximum (32.3 to 37.4 %) in these treatments. Highest disease control (65.85%) was achieved through the application of 0.1 % propiconazole but it was found to be on par with 0.1 % Thiophanate methyl (61.8%).

Viral Diseases

There are four significant diseases of banana that are caused by viruses (Jones, 2000, Ploetz *et al*. 2003).

Banana bunchy top

Banana bunchy top was first recorded in Fiji island, then the disease was subsequently recorded in Taiwan around 1900 and Egypt in 1901. It is believed that BBTD spread to Australia and Srilanka in 1913 through infected suckers from Fiji. The disease was introduced to India (Kerala) from Srilanka in 1943. The disease has now spread to Andhra Pradesh, Tamil Nadu, Orissa, Maharashtra, Bihar, Karnataka, West Bengal, Assam and Uttar Pradesh (Singh, 1996). In hilly regions of Tamil Nadu, this disease is present throughout the year and became an important constraint in hill banana cultivation.

Visual symptoms

Intermittent dark green dots and streaks of variable length is visible on leaf sheath, mid rib, leaf veins and petioles. Sometimes the typical streaks may not appear in some cultivars. The leaves produced are progressively shorter, brittle in texture, narrow and gives bunchy appearance at the top hence it is referred as bunchy top. The affected plants fails to produce flowers. If late infection occurs the plant can throw bunch but the fingers never develop to maturity. Marginal chlorosis in leaf lamina is also noticed. When infection occurs very late in the season the plant would show dark green streaks on the tip of the bracts. Some times the tip of male bud may become green and leafy (latent infection).

Transmission

BBTD is not sap transmissible but is presently transmitted by the banana aphid (*Pentalonia nigronervosa*). The nymphs transmit the virus in an efficient manner and are active during summer due to which the incidence was found to be more during this season. BBTV does not replicate in the aphid vector (Hafner *et al.*, 1997). The only confirmed hosts of BBTD are species within the genus Musa (*M. acuminata*, ***M.*** *balbisiana*, *M. ensete*, *M. sinensis*, *M. paradisica* and their hybrids) and *Ensete ventricosum.*

The virus

BBTV is most similar to the geminivirus but differs from that group in which the virions are isometric. The genome consists of atleast six components of ssDNA each of about 2.7 kb. The coat protein has a molecular weight of about 20000.

Management

The various approaches for the management include i) Exclusion, eradication and quarantine measures. Legislation should be introduced to prevent planting material being taken from plantations affected by bunchy top and to destroy any diseased plants. ii) Regular surveys by the most competent inspectors in new and old plantations (Ward law, 1972, Sastry *et al.*, 1980). iii) Selecting suckers from disease free areas. iv) Control of aphid vectors through injecting monocrotophos @ 0.1 % conc. at different heights during 3, 5 and 7th month after planting. (Ragupathy and Kulasekaran, 1980). Spraying dimethoate 500ml or monocrotophos 250ml/ha to control the vectors. v) Cross protection: Mild strain is available in Fiji islands (Simmonds, 1982). vi) Destroy infected plants *in situ* using 4ml of 2, 4, D (50g in 400 ml of water – 1: 8 ratio) solution. vii) Biocontrol using *Aphelinus colemani* as predator to control aphids, which has been tried in Taiwan. ix) Trangenic resistance : *Agrobacterium* mediated transformation has been adopted in Grand Naine cultivar (May *et al.*, 1995). x) Avoidance is more applicable to annual crops where planting time can be manipulated to avoid population peaks of aphid vectors. xi) Tissue culture plants are to be indexed for virus infection (Singh and Raj Sharma, 2002).

Banana Streak virus

Banana streak caused by Banana streak virus (BSV) and banana mosaic caused by Cucumber mosaic virus (CMV), are present in most areas where banana is grown. Before BSV and streak were described, streak symptoms were often confused with those of mosaic (Lochart, 1986). Atleast four strains of BSV that are linked to the B genome can be activated (become episomal) in A x B germplasm via meiosis and tissue cultured induced stress (Geering *et al.* 2001). They threaten progress in banana breeding programmes and safe movement of hybrid germplasm.

Banana streak virus disease has become a major threat to an economically important commercial group of banana, Mysore (AAB) cultivation which includes Poovan, Red banana, Robusta and Nendran. Of late, the tissue culture banana variety, Grand Nain has been affected severely by this virus. Nearly 80 per cent infection was observed in Poovan variety (Selvarajan *et al.,* 2004).

The virus

BSV is a plant pararetrovirus which contains non enveloped bacilliform particles having the size of 130 x 30 nm with double stranded DNA as their genome. Similar bacilliform badna viruses are reported to occur in Sugarcane and Citrus in India (Viswanathan and Selvarajan, 1996 ; Ahlawat *et al.,* 1996).

Transmission

BSV is transmitted in a semipersistent manner by citrus mealy bug, *Plannococcus citri* from banana to banana. Experimentally it has been proved that the sugarcane mealy bug, *Saccharicoccus sacchari* transmit ScBV from sugarcane to banana. This virus is not transmitted mechanically by sap or by tools used for inter cultivation operations. It has been proved that the virus is transmitted to new hybrids through the activation of integrants present in parents having B genomes. Tissue culture processes induce the expression of BSV disease symptoms. Ndowora *et al.* (1997) proved that BSV infection in hybrids is not from external sources but from endogenous pararetroviral sequences present in the host.

Diagnosis

It is known that BSV can exist in the host without producing any symptoms for longer periods and in addition the integration of viral genome in the host chromosome has caused problems to quarantine authorities and organizations involved in the exchange of Musa germplasm. There are many novel methods available to diagnose the virus from the host before exhibiting any known symptoms. Triple antibody sandwich ELISA (TAS- ELISA) has been used to detect the virus. ISEM and IC-PCR are the techniques involved in the detection of BSV.

Symptoms

Broken or continuous chlorotic streaks and spindle shaped lesions on leaves. Lesions may be sparse or concentrated in distribution. Chlorotic lesions become necrotic and blackened leads to black streaked appearance in older leaves. Narrow black streaks on the pseudostem and Internal necrosis of pseudostem also occurs. Peel splitting and necrotic streaks on fingers eg. Grand nain.

Transmission

Primary transmission through infected suckers. Secondary transmission through mealybug, *Planococcus citri*. Neither soil nor sap transmitted. Transmission from sugarcane (ScBV) is also reported. Seed transmission is reported by Daniells *et al*. (1995). Tetraploids are more susceptible to BSV. Tissue culture plants are more susceptible than the sucker plants.

Management

i) Phytosanitation – Roguing is used to remove unhealthy plants and substitute with healthy suckers. ii) Good farm management practices – Reduced water stress, mulching etc.,

Banana bract mosaic virus : *Poty virus*

Symptoms

Discolored streaks can be seen on the bracts due to which it is referred as BBrMV. Purple mosaic or streaking appears on the pseudostem, which is unique even after the removal of dead leaf sheaths. Separation of sheaths from the pseudostem also occurs. Suckers become distorted and deeply pigmented. Nendran is more susceptible to BBrMV. Other varieties like poovan, robusta, red banana, ney poovan, monthan are also susceptible (Selvarajan and Singh, 1997).

Transmission

Transmitted through infected suckers, corms and micropropagated plantlets. Through three species of aphids, *Rhopalosiphum maidis, Aphis gossypii* and *Pentalonia nigronervosa* (efficiency is 10 %).

Bacterial Diseases

Bacteria cause several types of diseases, the most significant of which are vascular wilts (Thwaites *et al*., 2000). With the exception of the Philippines, Moko caused by race 2 of *Ralstonia solanacearum* , is restricted to the western hemisphere. It has eliminated the highly susceptible Bluggoe (ABB) in many production areas in the west. In contrast, blood disease, caused by a *Ralstonia sp* is found in the Eastern hemisphere in only some islands of Indonesia. Moko and blood disease produce similar symptoms on banana and have modes of transmission that include transmission by flying insects. Recently the pathogen that causes bacterial wilt of enset, *Xanthomonas campestris pv. musarum* has implicated in a devastating epidemic on banana in Uganda (Thwaites *et al*. 2000 ; Tushemeriewe *et al*. 2003). A fruit rot, Bungtok which is caused by *R. solanacearum* is restricted to Phillippines. Less important, but more widely spread are rots of the rhizome and pseudostem that are caused by *Erwinia spp* (Thwaites *et al.* 2000).

Tip over or Head rot : *Erwinia carotovora*

Symptoms

Small sword leaves deviates from normal one. Rot occur in the middle tender leaf. Pseudostem easily comes out from corm portion when slight pressure is exerted. Oozing visible on the edges of corm and pseudostem confirm bacterial infection. It is severe during summer. It spreads through soil and infected sucker.

Management

Plant disease free suckers. Remove infected plants and destroy. Drench methoxy ethyl mercuric chloride (Emisan-6) 0.1%. Avoid drenching (Emisan-6) after shooting. Bleaching powder @ 4g /litre is recommended. Poovan is found to be resistant. Robusta is susceptible to this disease.

Diseases of Papaya

Foot rot / stem rot – *Pythium aphanidermatum* and *Phytophthora palmivora*

Symptoms

Water soaked patches appear on the stem at the ground level. Such patches enlarge and girdle the stem. Diseased tissues become darkbrown and rotten. Terminal leaves turn yellow, droop and wilt. Fruits become shriveled and dropoff. Severity increases with intensity of rainfall. One week old seedlings are more susceptible.

Management

Drenching of 1 % Bordeaux mixture or 0.2 % Copper oxy chloride -25 ml/ poly bag is recommended in the nursery. Either drenching 1 % Bordeaux mixture or 0.2 % Metalaxyl @ 2 litre per plant is recommended for the mainfield. It should be applied before the commencement of rainy season .

Ring spot – Papaya ring spot virus

PRSV, a type member of the genus *Potyvirus* of Potyviridae family (Fauquet, 1999) causes significant losses worldwide in papaya and cucurbits (Gonsalves, 1998).

Symptoms

On the leaves, veins become chlorotic that leads to vein clearing symptom. Puckering / bulging of leaf tissues between the veins and veinlets. Downward/ upward curling of young leaves. Leaf distortion which leads to shoe string like symptoms. Stunting of plants. On the stem, oily or water soaked lesions / dark green spots can be seen. On the fruits, characteristic ring spot symptoms can be seen and which is more distinct on matured fruits.

Transmission

PRSV is sap transmissible. The vectors viz., *Aphis gossypii* and *Myzus persicae* transmit the disease in a non-persistent manner. PRSV is neither soil nor seed transmissible.

Management

Growing border crops like maize or sorghum reduces the transmission efficacy of the vectors. Spraying insecticides at 15 days interval to keep the vectors under contol. Adjusting the date of sowing to avoid peak population of aphids.

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Eerspectives i 1 tegrated Disease Ma ageme t o(7ruit Crops

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Introduction

India is the second largest producer of fruits in the world with an annual production of 43 million tonnes from an area of 4 million ha and contributes more than 9% of world fruit production. Among the several tropical and subtropical fruits grown, mango contributes 32 per cent of the total exports followed by citrus (24 %) and apple (14%). In terms of foreign exchange processed fruit products and fresh fruits contributes a major share in total export earnings. Though, cultivation of fruit crops has a vast scope in increasing the national economy, over reliance on the usage of synthetic pesticides and fertilizers have necessitated a paradigm shift in the development of eco-friendly fruit crop management strategies to increase the productivity so as to meet the stringent demands of developed countries.

1.1 Status of pesticide consumption

The consumption of pesticides in Indian Agriculture has risen from 8620 tonnes in 1960 to 90,000 metric tonnes in 1996. Though the pesticide consumption pattern has increased several fold, the losses due to pests and diseases have not decreased instead the crop loss have currently increased to 15% as against 7.5% in 1960. Among various cultivated crops 13.2% of the total pesticides are used for the production of fruits and vegetables in India (Gopalakrishnan, 2002). Thus, the increased consumption pattern have not proved very effective but increased the environmental pollution, accumulation of toxic residues, development of resurgence and resistance among pests and pathogens.

1.2 Need for a paradigm shift

In recent times, accumulation of pesticide residues in the commodities resulted in rejection of agricultural commodities valued for a sum of 830 million US$. However, the varied agro climatic conditions in India and the demand for organically produced commodities in the International market strengthens the marketing of fruit crops and processed fruit products at International level. In order to meet the sanitary and phyto-sanitary standards prescribed by WTO, the plant protection and other agronomical technologies have to be reoriented to suit the demand of international markets. These mounting concerns warrant finding a suitable alternative green approach to mitigate the problems enforced by pesticide use. Currently, fungicides and insecticides of microbial and herbal origin play a vital role in integrated crop management (ICM). Hence, development of ICM modules for major fruit crops with IPM/IDM as a component will increase the national economy besides increasing the standard of living of Indian farmers. The implementation of such a system will enable a sustainable platform for centuries to come and should be given a high priority in society. This paper explains about the current status and various issues in IDM of fruit crops.

2.0 Need for IDM

The pests and diseases of horticultural crops were managed through the usage of pesticides. However, over dependence on the chemicals left plant protection in cross roads. The unlimited usage of pesticides and fungicides has led to the development of

1. Resurgence among the insects and resistance among pathogens
2. Outbreak of non-target secondary pests and pathogens
3. Suppression of beneficial organisms in the environment
4. Environmental pollution

The ill effects realized through the indiscriminate usage of pesticides and fungicides has warranted for the integration of IDM strategies for the management of diseases.

2.1 What is IDM?

Integrated Disease Management (IDM) is a system for accomplishing a specific goal: minimizing the impact of pathogens by using different modes of eco-friendly management practices in harmony with nature and attempting to decrease the overall chemical input into the environment. As such, it is composed of a number of steps; identifying the pathogen and its life history, establishing economic injury thresholds, monitoring, scouting and modeling populations, applying control tactics and assessing the success of the program. As with any system, IDM is impacted by the development of new technology. Many of the steps in IDM depend heavily on accurate and timely information and so can greatly benefit from the development of improved methods of accessing and disseminating information.

2.2 Steps in IDM

1. Identifying the pathogen, its damage and life history
2. Establishing economic injury thresholds
3. Monitoring, scouting and predicting populations
4. Selecting and applying management techniques
   - i.) Biological control
   - ii.) Cultural control
   - iii.) Host plant resistance
   - iv.) Biotechnological approaches (Transgenics)
   - v.) Integrated nutrient management
5. Evaluating treatment effectiveness

3.0 Biological control

There is an urgent need for new solutions to plant disease problems that provide effective control besides minimizing negative consequences on human health and the environment. Biological control, using microorganisms to suppress plant disease, offers a powerful alternative to the use of synthetic chemicals. The complexity of the interactions of biocontrol organisms, the involvement of numerous mechanisms of disease suppression by a single microorganism and the ability of most biocontrol agents to adopt to the environment in which they are used all contribute to the belief that biocontrol will be more durable than synthetic chemicals (Cook, 1993). However, success with biocontrol agents is often unpredictable and too variable.

The selection of biocontrol candidates should be done by considering the following norms so as to increase the stability of the performance of the formulations under diverse field environment to make the technology as a realistic one.

3.1 Significance of crop growth stage

The dynamics of PGPR, yeast, actinomycetes and pathogenic microbes are influenced by the exudates of living roots in the rhizosphere region, which in turn alters the communication network and interaction between the beneficial, deleterious microflora and the plant system as a whole (Picard *et al.*, 2000). The composition of root exudates varies depending on growth stages of the crop. It changes the distribution pattern and activity of rhizobacterial populations. Thus the stage of the plant development results in selection of a bacterial genotype that is distributed through out the crop growth period. The commonly occurring genotype irrespective of the crop growth stage should have the ability to produce antibiotics or antimicrobial substances that take care of various pathogens occurring in the infection court. Hence, understanding the distribution of genetic structure and the activity of a microbial community existing in the rhizosphere has a practical importance in the selection of a potential candidate for the management of plant diseases. This would facilitate to estimate the fate of released strains and their impact on both pests and disease causing organisms in the rhizosphere and phyllosphere due to the production of antibiotics (Picard *et al.*, 2000).

3.2 Role of antibiotic producers

The ability of rhizobacteria to suppress soil-borne and foliar pathogens depends on their ability to produce antibiotic metabolites such as pyoluteorin, pyrolnitrin, phenazine-1-carboxyclic acid (PCA), 2, 4 diacetyl phloroglucinol (DAPG), zwittermycin A and subtilin. Suppressive soils were frequently associated with antibiotic producing rhizobacteria. Among the antimicrobial metabolites, DAPG, phenazine and zwittermycin A has broad spectrum of action against a range of pathogens (Keel *et al.*, 2004; Fernando *et al.*, 2005). However, the influence of antibiotics of PGPR on the survival of plant parasitic nematodes and the effect of inorganic nutrients has not been investigated. Hence, selection criteria should be done based on the antifungal and antinemic potential of the selected organism for the sustained performance of antagonists in varied environment.

3.3 Why to go for consortial approach?

Although biocontrol agents perform well in the management of plant diseases they are highly sensitive to the fluctuations in the environmental conditions and are inconsistent in their performance. The consistency of biocontrol agents could be enhanced without resorting to genetic engineering. Since, nature is bestowed with millions of beneficial microbes, development of compatible cocktail of beneficial antibiotic producers of PGPR or bacterial endophytes would increase their efficiency hence, augmentation of compatible strain mixtures of PGPR strains to the infection court will mimic the natural environment and could broaden the spectrum of biocontrol against different plant pathogens (de Boer *et al*., 2003; Fernando *et al.*, 2005). Biological control of plant pathogens in disease suppressive soil is due to the existence of mixture of microbial antagonists in the rhizosphere. In addition, the strains that has the ability to produce antimicrobial peptides (chitinase and glucanase), induce systemic resistance by activating shikimate, octadecanoid and terpenoid pathways can be mixed and developed as consortia with different modes of action. Hence, consortium of either rhizobacteria or bacterial endophytes with multi faceted action could suit well for different ecological niche of fruit crops.

3.4 Optimization of delivery system

The success of biocontrol depends on the survival of antagonist in the infection court. It is decided based on the formulation and delivery systems. Hence, a suitable formulation with increased shelf life and appropriate delivery systems has to be designed to quench various pathogens to get reliable control. The delivery system used for the management of diseases of fruit crops include fruit spray, foliar spray, hive insert, soil application, sucker treatment, preharvest applications and bio-hardening . However, still we have to go a long way to standardize delivery system and frequency of application to ensure sustainable disease management.

3.4.1 Fruit spray

Pseudomonas syringae (10% wettable powder) in the modified packing line was sprayed at the rate of 10 g/l over apple fruit to control blue and grey mold of apple. The population of antagonist increased in the wounds more than 10 fold during 3 months in storage (Janisiewicz and Jeffers, 1997). Research on the exploration of PGPR has to go a long way to explore its usage to manage post harvest diseases too.

3.4.2 Foliar spray

Among various fruit crops grapes consume a large percentage of fungicides for the management of mildews and anthracnose. Most of the fungicides are not equally effective in controlling mildew under field conditions. This led to the introduction of several newer fungicidal molecules. The new molecules are also not highly effective under high inoculum build up. Moreover several rounds of application of fungicides results in accumulation of residues beyond the permissible limit. Studies on the development of eco-friendly strategies reflect that foliar application of fluorescent Pseudomonads performed equally to fungicides. But, the sustainable effect of fluorescent pseudomonads and other PGPR could be achieved through the development of oil based liquid formulations with increased shelf life (Nakkeeran *et al*., 2005).

3.4.3 Hive insert

Honey bees and bumble bees serve as a vector for the dispersal of biocontrol agents for the control of diseases of flowering and fruit crops. An innovative method of application of bio-control agent right in the infection court at the exact time of susceptibility was developed by Thomson *et al.* (1992). *Erwinia amylovora* causing fire blight of apple infects through flower and develops extensively on stigma. Since flowers do not open simultaneously the bio-control agent *P. fluorescens* has to be applied to flowers repeatedly to protect the stigma. Nectar seeking insects like *Aphis mellifera* can be used to deliver *P. fluorescens* to stigma. Bees deposit the bacteria on the flowers soon after opening due to their foraging habits. Honey bees have also been used for the management of gray mold of strawberry and raspberry (Peng *et al*., 1992).

3.4.4 Soil application and sucker treatment

Plant growth promoting rhizobacteria also play a vital role in the management of soilborne diseases of vegetatively propagated crops. The delivery of PGPR varies depending upon the crop. In banana rhizobacteria are delivered through rhizome treatment. Banana suckers were dipped in talc based *P. fluorescens* suspension (500g of the product in 50 liters of water) for 10 min after pairing and pralinage. Subsequently it was followed by capsule application (50 mg of *P. fluorescens* per capsule) on third and fifth month after planting and resulted in 80.6 per cent reduction in panama wilt of banana (Raguchander *et al*., 2000).

3.4.5 Preharvest applications

Postharvest decays of fruits are controlled by pre and post harvest spray of bioagents.The antagonistic yeasts *Cryptococcus infirmo-miniatus*, *C. laurentii*, and *R. glutinis*, applied to pears 3 weeks before harvest maintained high population densities through harvest and reduced gray mold (Benbow and Sugar, 1999). Population of *Aureobasidium pullulans*, *Pichia guilliermondii* and *B. subtilis* increased after application to apples in the orchard and were maintained at relatively high densities on fruit in cold storage, except for *B.subtilis*, which declined later (Leibinger *et al*., 1997). Mixtures of these antagonists controlled blue and gray molds and bull's-eye rot caused by *Pezicula malicorticis* as effectively as the fungicide, Euparen and were more effective than the individual antagonists in tests on apples after harvest.

Field applications of various antagonists including *Gliocladium roseum, Trichoderma harzianum, B. subtilis*, and *B. licheniformis*, yeast and other bacteria from bloom until harvest have variable success. The best control, however, was obtained with the application of pyrrolnitrin, a secondary metabolite from the biocontrol agent *P. cepacia*, on harvested fruit to control postharvest decays. Anecdotal evidence suggests that postharvest infection originating from wounds made by pickers, basket abrasions, and handling may be a major cause of strawberry decay. Perhaps biocontrol efforts should be focused on the control of these kinds of infections. In this respect, there is a recent, promising report on the successful biocontrol of strawberry decay with postharvest application of *Candida reukaufii*, *C. pulcherrima*, and strains of Enterobacteriaceae isolated from strawberry fruits (Guinebretiere *et al*., 2000). In the examples above, significant biocontrol of postharvest decays on the same kind of fruit was achieved with both field and postharvest applications. Combining field and postharvest application of biocontrol agents should lead to even more effective control of postharvest decays (Table 1).

3.4.6 Bio-hardening

Colonization of micro propagated clones such as banana or amendment of PGPR or bacterial endophytes to the transplant mix of vegetative propagated fruit crops increase vigor of the seedlings and develop resistance to diseases. *In vitro* inoculation of grapevine plantlets with *P. fluorescens* induced a significant plant growth promotion which made them more hardy and vigorous when compared to non inoculated plantlets. This ability increased upon transplanting. When grown together with *B. cinerea*, the causal agent of gray mould, significant differences of aggressiveness were observed between the inoculated and non-inoculated plants. The presence of bacteria was accompanied by an induction of plant resistance to the pathogen (Barka *et al*., 2000). Inoculation of chitinolytic rhizobacterium, *Serratia plymuthica* strain HRO-C48, as a bare root transplant dip reduced the disease caused by *Verticillium* and *Phytophthora* besides increasing the yield. Soil-less transplant media amended with a formulation of PGPR designated LS213 improved plant vigor, reduced disease severity and increased yield of strawberry (Kurze *et al*., 2001). Similarly bio-hardening of tissue culture banana under in vitro and in transplant mix, application of PGPR to the cut ends of root stock and scion of mango grafts and in other fruit crops will aid in early establishment of PGPR/endophytes and thereby will increase the vigour, disease resistance and yield of the crop. Hence addressing research on bio-hardening of vegetative propagated fruit crops will pave as a successful component to IDM.

4.0 Bioefficacy of PGPR

The use of PGPR and yeasts has been reported for the control of fungal pathogens in different cropping systems. Application of PGPR strain FP7 with chitin bio-formulation at pre flowering stage significantly suppressed mango anthracnose under endemic conditions. The strain FP7 with chitin showed durable ISR throughout the postharvest period as compared to carbendazim (Vivekanandhan *et al*., 2004). Hardening of rhizomes with *Bacillus sp., Pseudomonas fluroscens*, and bacterial consortia reduced Fusarium wilt and anthracnose of banana under field conditions via inducing systemic resistance. Foliar application of *P. fluroscens* reduced downy mildew and grey mould of grapes. Biohardening of banana rhizomes with Pf1, CHAO strains of *P. fluroscens* and endophytic Bacillus reduced the incidence of banana bunchy top (Vide Samiyappan *et al.*, 2005).Though several research has been conducted to find suitable alternate for the management of diseases of fruit crops, the research on method of application, standardization of biohardening protocols, frequency of application of bioagents and their mechanism in disease reduction has to be investigated thoroughly so as to develop IDM module for fruit crops.

5.0 Transgenic plants

A major goal in crop protection is development of increased and durable resistance to a spectrum of diseases. In the past, durable resistance to diseases has been sought through traditional breeding approaches or by the widespread application of pesticides. Both approaches have proved transient. Transgenic approaches will be a component in IDM to develop multiple resistances against different pathogens. Over expression of a single component of the plant defense response in all plant tissues improved disease resistance. However in many cases the extensive cellular reprogramming associated with defense will reduce yields, if uncontrolled defense reactions are activated in uninfected cells (Hammand- Kossack and Parker, 2003). Advances in promoter technology have lagged behind gene discovery. But development of a series of tightly-controlled promoters is required for achieving desired temporal and spatial regulation of the transgenes. Recent advances in synthetic promoter technology enable production of novel promoters that direct tighter regulation of the transgene. Therefore pathogen inducible promoters would increase the chances of boosting disease resistance because they limit the cost of resistance by restricting expression to infection sites. Furthermore, the promoter should not be auto activated by the transgene. Because, it would lead to uncontrolled spread of gene expression; so-called 'runaway cell death' (McDowell and Wofenden, 2003). Hence research has to be addressed towards the development of transgenic fruit crops with pathogen inducible promoters having broad spectrum of action to various pathogens rather than constitutive and tissue specific promoters.

6.0 Nutrient management

Microbes play a pivotal role in enriching soil health and there by maintains the plant health. Several fruit crops continue to remain productive in spite of any specific input. It indicates the role of microbes in ensuring crop growth and productivity. In majority of the fruit crops organic recycling through addition of biomass to the soil resulted in maintaining the organic status of the soil, which improved the soil structure and nutrient availability. In plantation crops the increased yield was attributed to the increased rhizosphere activity mainly due to the population build up of IAA producing bacteria like *Eschericia* spp., and also gibberellins producing *Aspergillus flavus* and *A. fumigatus*. In addition the population dynamics of phosphorus solubilizers such as *Bacillus* spp., and *Pseudomonas* spp., increased considerably and improved the crop health through phosphorus mobilization.

High density multiple cropping adopted in root wilt affected coconut belts as a disease management strategy decreased the intensity of root wilt based on the foliar index and consequently increased the yield. The increase was attributed to increased microbial activity especially due to the PGPR in the rhizosphere and nutrient build up (Sharma *et al*., 2003). Many of these microbial interventions clearly indicated the significance of PGPR in integrated nutrient management (INM) in cropping systems. However, the potential of the PGPR and other microbes as a component in INM in fruit crops remain unexplored and needs to be exploited systematically.

7.0 Conclusion

In recent years, there is an increasing demand for the organically produced commodities in the international market. There is an urgent need to develop guidelines and designate agencies for accreditation of produce for meeting the international standards. The international standards could be met through the adoption of IPM/IDM modules in fruit crops so as to produce residue free products. The same could be achieved through reorientation of research and Government policies that suit the producers and end users. Hence, the following research issues have to be addressed on war foot to meet the challenging demands of the developed countries.

- Improved cost benefits analyses
- Assessment of human health risks related to IPM/ IDM
- Constraints in commercialization of biopesticides
- Strengthening research on biocontrol of foliar and post harvest diseases
- Strengthening the basic information on plant pathogen biology

Table 1: Biological control of post harvest diseases of fruits

Crop	Disease	Antagonist
Grape	Botrytis rot	*Pichia guilliermondii*
Avocado	Antracnose	*Bacillus subtilis*
	Stem-end rot	
Strawberry	Botrytis, Rhizopus rot	*Aureobasidium pullulans, Candida oleophila*
Apple	Blue mould	*Aureobasidium pullulans*
	Botrytis rot	*Rhodotorula glutinis*
	Bull's-eye rot	*Bacillus subtilis*
Sweet cherry	Botrytis rot	*Aureobasidium pullulans*
Strawberry	Botrytis rot	*Aureobasidium pullulans*
Table grape	Botrytis rot	*Aureobasidium pullulans*
Wine and Table grape	Botrytis rot	*Yeasts and yeast like-fungi*
	Rhizopus rot	*Yeasts and yeast like-fungi*
	Aspergillus rot	*Yeasts and yeast like-fungi*
Apple	Blue mould	*Candida sake*
Apple	Blue mould	*Aureobasidium pullulans*
	Botrytis rot	*Cryptococcus laurentii*
		Rhodotorula glutinis
Table grape	Botrytis rot	*Aureobasidium pullulans*
Pear	Botrytis rot	*Cryptococcus inxrmo- miniatus; Cryptococcus laurentii; Rhodotorula glutinis*
	Blue mould	
	Side rot	

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Nematode Ma ageme t i Ba a a a d Eapaya

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Banana

Banana is one among the five major fruit crops in India. It occupies 37 per cent of the total fruit production. Nematodes are serious constraints in banana apart from several other parasitic pathogens. A total of 132 species of nematodes belonging to 54 genera are reported to be associated with the rhizosphere of banana in the world. Out of these, 71 species of nematodes belonging to 33 genera are recorded from banana in various parts of India. Crop losses caused by nematodes are very high, with an average annual yield loss of about 20 per cent worldwide. Nematodes attack the root and corm tissues of banana and modify the plant physiological functions by obstructing the water and nutrient uptake, thus resulting in the poor anchorage of whole plant growth and yield (Tech. Bulletin #10, NRCB).

1.1 Nematodes associated with banana

The most destructive and widely distributed nematode is the burrowing nematode, *Radopholus similis* which is one among the ten most destructive nematodes, followed by root lesion nematode, *Pratylenchus coffeae*. The other economically important parasites of banana having regional significance are root knot nematodes, *M.incognita, M.javanica*; the spiral nematode, *Helicotylenchus multicinctus, H. dihystera;* cyst nematode, *Heterodera oryzicola* and reniform nematode, *Rotylenchulus reniformis*. The other important nematodes which are closely associated with banana are: *Hirschmanniella oryzae,Tylenchorhynchus coffeae, Hoplolaimus indicus, Rotylenchus spp., Paratylenchus spp., Longidorus spp., Xiphinema spp.*, and *Tylenchus spp*. But their pathogenicity has not been investigated.

1.2 Association of nematodes with other micro organisms

Fungi in association with nematodes are known to aggravate the initial nematode damage or inhibit the nematode multiplication. Among the various constraints limiting the banana fruit production, the Fusarium-Nematode disease complex is a serious concern causing crop losses worth millions of rupees annually. The plant parasitic nematodes (*Radopholus similis, Helicotylenchus multicinctus, Pratylenchus spp., Meloidogyne incognita, Hoplolaimus sp.* and *Heterodera sp*.) infect banana roots and predisposes them to *Fusarium oxysporum* f. sp. *Cubense*, causing wilt complex. The major banana groups found susceptible to fungal nematode complex are Silk, Pome, Monthan, Rasakadali, Neypoovan and Tellachakrakali. These susceptible varieties are cultivated in Tamil Nadu, Kerala, Karnataka, Andhra Pradesh, Bihar, West Bengal, Assam, Nagaland and Manipur in India. The existence of synergistic interaction between the nematodes and wilt pathogens in banana has been well documented.

2. Nematode management

2.1 Nematicidal management

Carbofuran @40g/sucker is used to manage nematode population. Attempts towards the management of fungal nematode complex through out the world reflect that phorate (nematicide) and carbendazim (fungicide) has been used on a large scale to control fungal nematode complex. However, most of the chemical nematicides are not effective because, the plant parasitic nematodes spend their life cycle in the soil and inside plant roots. In addition, the target of chemical nematicides often resides at a fair distance away from the site of application. More over, the nematode cuticle and other surface structures are impermeable to many organic molecules. Consequently, most of the nematicides have low specificity in controlling nematodes in addition to being highly toxic or volatile and also cause human or environmental pollution, such as ground water contamination or ozone depletion (Chitwood, 2002).

2.2 Cultural management

This involves fallowing the land for three months after banana harvest and summer ploughing, use of oil cakes of neem, mahua, castor etc.,@ 500g / sucker at planting and there after at fourth month, press mud application @ 3-5kg/ sucker, crop rotation with paddy, sugarcane, green gram or cotton, intercropping with sunnhemp, cowpea and marigold, which significantly reduced the nematode population in the field.

Nematode deterrent plants

Enemy plants	Active principle	Nematodes reduced
Mustard	Allyl isothiocyanate	*Cyst nematode*
Marigold	Terthienyl	*Tylenchorhynchus, Helicotylenchus spp., Hoplolaimus spp., Rotylenchulus reniformis, and Pratylenchus spp.*
Asparagus	Asparagusic acid	*Trichodorus christei*

2.3 Physical management

Paring the corms free of all necrotic lesions and immersing in hot water at 50-55^{0}C for 30 minutes renders a nematode-free planting material. Sun drying of corms for one or two weeks is also advisable.

Hot water treatment for denematisation of planting material

Nematode genera	Planting stock	Duration (min.)	Temp. (ºC)
Helicotylenchus multicinctusMeloidogyne spp.	Banana corm	20	55
Pratylenchus spp.	Banana corm	20	55
Radopholus similis	Banana corm	10	50

2.4 Host resistance

Banana lines Anaikomban, Pisang Lilin, Pisang Jari Buaya, Kunnan, Vennetukunnan, Thenkunnan, Yagambi km5 were found to be resistant to the burrowing nematode.

Some of the nematode resistant cultivars include Kadali, Ayiramkaal Poovan, Poovan, Pey Kunnan, Vennettu Kunnan, Tongat and Anaikomban. Several banana hybrids have been found to be tolerant to nematodes which are effectively being used in breeding programme.

2.5 Biological management

Use of biological agents such as *Pseudomonas fluorescens*, *Trichoderma viride*, VA mycorrhiza, *Glomus fasciculatum* and *Pasteuria penetrans* are effective in reducing nematode population in soil and roots of banana.

2.5.1 Pseudomonas fluorescens: They are a group of plant growth promoting rhizobacteria (PGPR) in the biocontrol of plant parasitic nematodes. They suppress nematode population by producing certain toxins and also make unavailable iron available to plants (by iron chelating process-siderophores).

2.5.2 Pasteuria penetrans: This bacterium has a wide host range and parasitise 200 nematode species belonging to 96 genera from 10 orders of the phylum nematode. *P.penetrans* reduces root penetration by the nematode juveniles, causes sterility of the parasitized nematode, inhibitory of the reproductory system to development, inhibits egg formation and reduce nematode population.

2.5.3 **VAM:** Plant-parasitic nematodes and VAM fungi commonly occur together in the roots or rhizosphere of the same plant, each behaving the characteristic way but opposite effect on plant vigour.

2.5.4 Paecilomyces spp.**:** *P. lilacinus* is effective parasites of *Meloidogyne* eggs. They are more effective in reducing nematode population.

Nematode eggs of the group Heteroderidae and those deposited in a gelatinous matrix are more vulnerable to attack by these organisms than those of migratory parasites. Once in contact with the cysts or egg masses, the fungus grows rapidly and eventually parasitizes all the eggs that are in the early embryonic developmental stages.

3. Nematodes of papaya

Root knot (*Meloidogyne incognita*) and reniform (*Rotylenchulus reniformis*) nematodes infest papaya. Feeding nematodes cause root swellings or root galls, resulting in yellowing and premature abscission of the leaves. Since nematicide treatments are expensive, it is important to use clean land, not replanting papaya in the same field.

Above-ground symptoms of heavily infected plants appear as moderate to severe leaf chlorosis and plant stunting. Some wilting may occur during periods of peak transpirational stress on the plant. Papaya roots attacked by root-knot nematode shows varying degrees of galling depending on the numbers of the nematode in the soil or the subsequent hatching of eggs, migration of the larvae and reinfection of surrounding tissue. Unlike the reniform nematode, the female root-knot nematode and most of her eggmass are usually completely imbedded in the root tissue. Hence, dissection of the root is mandatory before a positive identification can be made. Root systems may be somewhat reduced because terminal infections of roots cause a slight swelling and cessation of further elongation.

Severe galling of roots and stunting of Papaya due to root-knot nematodes has been observed primarily in sandy soils. Galling may be so extensive on seedlings that they may be killed as a result. In some loam or clay soils, galling is light to moderate without noticeable above-ground symptoms.

3.1 Biology

Papaya is susceptible to the four most common species of root-knot nematodes, especially *Meloidogyne incognita* (Kofoid and White) Chitwood and *M. javanica* (Treub) Chitwood. *Meloidogyne arenaria* (Neal) Chitwood and *M. hapla* Chitwood are found less often; the latter species prefers cooler temperatures and may damage papayas grown at higher elevations.

The second-stage juvenile of the root-knot nematode is less than 500 µm long. Penetration of the root by this juvenile occurs generally near the root tip. When the female juvenile begins feeding in the central cylinder region of the root, giant cells are formed. Surrounding root cells begin to increase in size and number, resulting in the distorted, massive enlargements known as knots or galls. During the process of gall formation, the sedentary female undergoes several molts until her body is flask or pear-shaped and completely imbedded in root tissue. If several nematodes infect in the same general vicinity, a large gall occurs, which completely encloses all the females and their eggmasses. In single root-knot juvenile infections, there is little or no observable root swelling and the gelatinous matrix exudes to the outside of the root and resembles that of the previously described reniform nematode eggmass. A single female deposits an average of 350 eggs in the eggmass. Under subtropical and tropical conditions, as many as 14 to 17 generations are possible in one year's time. The debilitating effects of the nematode on the plant may involve: 1) competition for nutrients and food, 2) a reduced root system, 3) impaired uptake of water and nutrients because of a distorted vascular system, and/or 4) predisposition to fungal root rots.

3.2 Epidemiology

Because of their small size, root-knot nematodes do not traverse distances of more than a few inches in their lifetime. Root-knot nematodes are principally spread through cultivation and surface run-off or irrigation water.

3.3 Management

Nematodes can be controlled by the application of carbofuran 3G @ 3g/ polybag at nursery stage and 33 g per plant at planting pit and at flowering stage in the main field. Combined application of neem cake @ 250g + carbofuran 3G @ 33g + *Pseudomonas fluorescens* formulation @ 4g may be applied /pit in the main field.

Conclusion

Although the emphasis on integrated pest management over the past three decades has promoted strategies and tactics for nematode management, comprehensive studies on the related soil biology–ecology are relatively recent. Traditional management tactics include host resistance (where available), cultural tactics such as rotation with nonhosts, sanitation and avoidance and destruction of residual crop roots, and the judicious use of nematicides. There have been advances in biological control of nematodes, but field-scale exploitation of this tactic remains to be realized. New technologies and resources are currently becoming central to the development of sustainable systems for nematode-pest-crop management: molecular diagnostics for nematode identification, genetic engineering for host resistance, and the elucidation and application of soil biology for general integrated cropping systems. The latter strategy includes the use of nematode-pest antagonistic cover crops, animal wastes and limited tillage practices that favor growth-promoting rhizobacteria, earthworms, predatory mites and other beneficial organisms while suppressing parasitic nematodes and other plant pathogens. Certain rhizobacteria may induce systemic host resistance to nematodes and in some instances, to foliage pathogens. The systems focusing on soil biology hold great promise for sustainable crop-nematode management, but only a few research programs are currently involved in this labor-intensive endeavor (Barker and Koenning, 1998).

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Plant parasitic nematodes are one of the major limiting factors in the production of fruit crops throughout the country. For centuries, man has been plagued by these microscopic organisms feeding on the roots of crop plants essential to his survival. Roots damaged by the nematodes are not efficient in the utilization of available moisture and nutrients in the soil resulting in reduced functional metabolism. Further more, roots infested and damaged by nematodes are easy prey to many types of fungi and bacteria which invade the roots and accelerate the disease. These deleterious effects on plant growth result in reduced yields and poor quality of crops. Nematode management is therefore important for high yields and quality that are required in modern crop production.

Chemical nematicides have been routinely used to control nematode diseases in high value fruit crops. But their prohibitive costs and associated health hazards lay special emphasis on evolving integrated nematode management as the best alternative. Major nematode pests, their damage symptoms and integrated nematode management practices in economically important fruit crops are discussed.

BANANA (*Musa* spp.)

Banana is the most popular fruit crop grown in the tropical and sub tropical conditions. More than 132 species belonging to 54 genera of nematodes are in association with the crop. The most important are the burrowing nematode, *Radopholus similis*, the spiral nematode, *Helicotylenchus multicinctus*, the lesion nematode, *Pratylenchus coffeae* and the root knot nematode, *Meloidogyne* spp.

1. Burrowing nematode (*Radopholus similis*)

The burrowing nematode, *Radopholus similis* was first reported on banana from Kerala by Nair *et al.* (1966). It causes the disease known as root rot or black head or toppling disease in banana. It causes yield loss up to 41 per cent.

Symptoms

R. similis burrows into the roots and corm at any point feeding on the cortical cells and killing the invaded tissues. The infested plants show retarded development and stunted growth with lanky pseudostems, foliar chlorosis and small bunches. 'Tip over' (sudden toppling of plants) occurs even with slight wind or flood due to poor anchorage. The infected plant roots and corm show characteristic reddish brown lesions due to feeding and destruction of cells.

Interaction with other microorganisms

The lesions induced by *R. similis* facilitate the entry of *Fusarium oxysporum* f. sp. *cubense* causing the Panama wilt disease (Jonathan and Rajendran, 1998). Even in wilt resistant cultivar like Lacatan, breakdown of resistance was observed in the presence of the nematode.

2. The spiral nematode (*Helicotylenchus* spp.)

Das (1960) reported the banana spiral nematode *Helicotylenchus multicinctus* from Hyderabad for the first time in India. It has both endo and ectoparasitic life in banana. They are distributed in all banana growing areas and cause serious decline in banana.

Symptoms

The spiral nematode produces superficial lesions which resemble pustule like eruptions. Such lesions cause extensive root necrosis and die back of roots eventually leading the plant to debilitation.

Interaction with other microorganisms

The lesion produced by this nematode are colonized by fungi especially by *Fusarium*, *Rhizoctonia* and *Cylindrocarpon* leading to further rotting of roots.

3. Lesion nematodes (*Pratylenchus coffeae*)

Nine species of *Pratylenchus* have been found infecting banana throughout the world but the major pathogenic species is *Pratylenchus coffeae.*

Symptoms

The lesion nematodes feed and destroy the cortical parenchyma cells as a migratory endoparasite causing root lesion. The initial entry of the nematode into the root produces a reddish elongated fleck which enlarges as the nematode continues to feed. The older parts of the lesions turn black and shrink while the margins remain red. The nematode attacked plants show poor growth, chlorotic leaves and reduced bunches.

4. Root - knot nematode (*Meloidogyne* spp.)

Except *M. hapla* all the other three major root - knot nematode species *viz*., *M. incognita, M. arenaria* and *M. javanica* readily infest banana (Jonathan *et al.,* 1999).

Symptoms

This is a completely sedentary endoparasite feeding on the xylem - phloem tissues causing root atrophy. They produce small galls on the fibrous roots and about 10 - 15 females are found in a single small root gall. The nematode attack on fleshy roots often leads to splitting and cracking of roots.

Integrated nematode management in banana

1. Physical control

Paring the planting materials by trimming away necrotic lesions and immersing it in hot water at 50 - 55°C for 20 minutes renders nematode free planting materials.

2. Cultural control

- **Crop rotation:**

  i. Rice or green gram after banana reduces *R. similis, P. coffeae* and *H. multicinctus* (Rajendran *et al*., 1979)

  ii. Rotation with sugarcane, sorghum, tobacco, cassava and grapefruit increased banana yield and suppressed the population of *R. similis*.

- **Fallowing**

  Fallowing for a period of three months after banana effectively suppressed the burrowing nematode population (Rajendran *et al.,* 1979).

- **Flooding**

  Flooding the soil for 3 - 7 weeks after removal of all rhizomes, led to the disappearance of *R. similis* and *H. multicinctus* (Sarah *et al.,*1983)

- **Intercropping**

  - Intercropping of banana with *Crotalaria juncea* was found to reduce *R. similis.*
  - Marigold (*Tagetes* spp.) can be grown in between suckers and incorporated around the plants.

3. Biological control

Inoculation of VAM (*Glomus fasciculatum*) resulted in vigorous root growth and reduced nematode population.

4. Organic amendments

- Application of neem cake @ 400g/plant once at planting and second after 4 months reduced *R. similis, Helicotylenchus* sp. and *Pratylenchus* sp.
- Soil covers with banana trash or sugarcane leaf trash reduced *R. similis* and *P. coffeae*.
- Application of FYM (25t/ha) and pressmud (15t/ha) encourage predacious nematodes and antagonistic fungi which in turn reduced the nematode infestation.

5. Plant resistance

- Varieties like Gros Michel, Bodles Atlaport, Pisang Lilin & Lacatan are resistant to *R. similis.*
- Banana cultivars *viz*., Kadali, Pedalimoongil, Kunnan, Ayiramkapoovan, Peykunnan and Anaikomban have been reported to be tolerant / resistant to the burrowing nematode (Parvatha Reddy *et al.,* 1989).

6. Chemical

- Paring and pralinage of suckers with carbofuran 3G @ 40g / sucker (or) paring and soil application of carbofuran 3G at 40g / plant before three months after planting.
- Dipping the pared suckers in monochrotophos 36 EC @ 0.05% before planting.

Citrus

Citrus is an important fruit crop and ranks third in area after mango and banana. About 122 species of plant parasitic nematodes are associated with the citrus spp. Among them, *Tylenchulus semipenetrans*, *Radopholus similis*, *Meloidogyne* spp., *Pratylenchus* spp., *Xiphinema* spp. and *Hoplolaimus* spp. are often associated with the crop.

1. Citrus nematode (*Tylenchulus semipenetrans*)

Siddiqi (1961) first reported the citrus nematode, *Tylenchulus semipenetrans* in India. It is a semi endoparasite which causes slow decline of citrus and considered to be one of the factors responsible for die – back disease of citrus trees in India. Crop loss is estimated to be 8.7 to 12.2 per cent due to this nematode.

Symptoms

Nematode affected trees exhibit reduced vigour, chlorosis and falling of leaves, twig die back and consequently reduced fruit production. The decline of the tree is gradual and persists until the crop is so small that the tree maintenance may become uneconomical. Heavily infected roots are darker in colour with branch rootlets shortened, swollen and irregular in appearance than in normal ones.

Interaction with other microorganisms

The association of nematode with *Fusarium oxysporum* and *F. solani* leads to death of plants.

2. Lesion nematode (*Pratylenchus coffeae*)

P. coffeae is responsible for citrus slump disease in Florida. The nematode root rot of citrus in Uttar Pradesh is principally caused by *P. coffeae*.

Symptoms

Due to nematode penetration and feeding, black lesions are produced in the cortex. These lesions gradually expand and coalesce to girdle the roots. Affected plants exhibit poor growth, general die back and produce undersized fruits.

3. The lance nematode (*Hoplolaimus indicus*)

Symptoms

It reduces the plant growth and the symptoms are usually visible in 3 – 4 year old citrus orchards.

4. Root knot nematode (*Meloidogyne* spp.)

The root knot nematode species like *M. javanica, M. africana* and *M. indica* are recorded in citrus orchards in India. *M. javanica* infested trees are poor in vigour, unthrifty in appearance and show severe stunted growth. They fail to flower and produce fruits even after several years of planting.

Integrated nematode management in citrus

1. Cultural control

- Selection of nematode free planting materials to prevent the introduction of nematode inoculum into orchards.
- Intercropping with *Crotalaria* exerts toxic effect on root knot nematode
- Application of castor cake is highly effective against citrus nematode (Singh and Sitaramaiah, 1973). Also neem, mahua, groundnut and mustard oil cakes are effective in reducing nematode population in citrus rhizosphere.

2. Plant resistance

Trifoliate orange (*Poncirus trifoliata*) and its hybrid (Citrumello) are highly resistant to citrus nematode.

3. Biological control

- *Pasteuria penetrans* can be multiplied readily on citrus nematode and offers potential for bio control of *T. semipenetrans*
- Several species of nematode trapping fungi of the genera *Arthrobotrys*, *Dactylella* and *Dactylaria* have been found in association with citrus nematode.
- Fungal parasite *Paecilomyces lilacinus* consistently and effectively controlled the population of *Meloidogyne* sp.
- Application of *P. fluorescens* @ 20g / tree thrice a year at 15 cm depth and 50cm away from the trunk.

4. Chemical control

- Application of carbofuran 3G at 100g / tree at 15 cm depth in the tree basin
- Drenching the soil around the plant with dimethoate and fensulfothion also found effective against nematodes.

GRAPEVINE (*Vitis vinifera* L.)

Grapevine is one of the important commercial crops grown in different climatic zones of the world. In India, about 29 species within 15 genera of parasitic nematodes have been reported in association with grapevine. However the root – knot nematode

Meloidogyne incognita, lesion nematode (*Pratylenchus* spp.) and the reniform nematode, *Rotylenchulus reniformis* are the most important nematodes infesting the crop.

1. Root knot nematode (*Meloidogyne incognita*)

The root knot nematodes cause yield loss upto 25 to 50 per cent in grapevine. Young, shallow rooted vines are often affected by the nematodes.

Symptoms

Patches of poorly branched vines with scant foliage, pale and small leaves and poor bearing are the indications of root knot nematode damage. In young plants, premature decline, weak vegetative growths are commonly associated with nematode infestation. The root system shows typical localized swellings particularly on feeder roots and young secondary roots. *M. incognita* stimulates the production of many new fine rootlets above the site of nematode infection resulting in 'hairy root' condition (Baghel, 1992).

2. Root lesion nematodes (*Pratylenchus* spp.)

Pratylenchus vulnus commonly found on grape is economically more important and its occurrence and severity is more in heavier soils.

Symptoms

Plants infected with *P. vulnus* show loss of vigour and reduction in fruit production. Infected young vines remain very weak, often fail to establish root system and eventually die. Roots distinctly show lesions which are initially brown and later on turn black.

3. The reniform nematode (*Rotylenchulus reniformis*)

It is a semi endoparasite inserting its head and neck inside the root and exposing the posterior reniform body outside the root.

Integrated nematode management in grapevine

1. Physical control

- Hot water treatment of rootings at 51°C for 5 minutes is effective against nematodes. The vines should then be cooled and planted immediately.

2. Cultural control

- Use of nematode free planting materials for raising the garden
- Intercropping with *Tagetes patula* reduce 39.44% nematode population (Baghel, 1992).

3. Plant resistance

- Dogridge, Salt creek, Harmony, St. George are well known nematode resistant root – stocks.

4. Organic amendments

- Neem cake can be applied @ 250g/ vine and FYM can be applied @ 1kg / vine.

5. Biological control

- Application of *Pseudomonas fluorescens* @ 4g / vine

6. Chemical control

- Soil application of carbofuran or phorate granules @ 1.5 kg a.i. / ha effectively checks the reniform nematode. The nematicides can be applied immediately after pruning.
- Application of carbofuran 3G @ 60g / vine or phorate 10G @ 20g / vine reduces *M. incognita* population.

PAPAYA (*Carica papaya*)

Papaya is an important fruit crop grown in tropical and subtropical climates in India. The root knot nematode, *Meloidogyne incognita* and reniform nematode *Rotylenchulus reniformis* cause serious damage to the crop. Studies indicated 20 – 40% yield loss in the crop due to nematode infestation.

1. Root knot nematode (*Meloidogyne incognita*)

Meloidogyne javanica and *M. incognita* have been reported to be major nematode pests of papaya.

Symptoms

General symptoms visible in field include poor growth, yellowing of foliage and weak vigour. Roots exhibit typical galls and during heavy infection, adjacent galls join together and form large galls. The lateral branching of roots is limited (Baghel, 1992).

2. Reniform nematode (*Rotylenchulus reniformis*)

R. reniformis was first reported on papaya by Prasad *et al.*, (1964) from North India.

Symptoms

Nematode affected plants are stunted in growth. Foliage is slightly yellow in colour with reduced leaf size (Khan and Khan, 1998).

Nematode injuries facilitate easy entry of soil borne fungal pathogens *viz*., *Phytophthora* and *Fusarium* causing root rot disease.

Integrated nematode management in papaya

1. Cultural

- Selection of nematode free papaya seedlings for planting.
- Summer ploughing and exposing the soil to sunlight for one or two months during April – May reduce the nematode and pathogen load in soil.
- Crop rotation with marigold reduce nematode incidence for the next crop.

2. Organic amendments

- Application of FYM, neem cake, pressmud and carbofuran 3G at 8kg, 100kg, 3kg and 10g respectively per plant at the time of planting in the pit.

3. Chemical control

- Prophylatic drenching with Bordeaux mixture at 0.1% at monthly intervals during the north – east monsoon period.
- Application of 25 ml of copper oxychloride (1g / lit) and 1g of carbofuran 3G / polybag, 15 days after sowing containing one seedling.
- Application of carbofuran 3G at 40g / tree before flowering.

4. Plant resistance

- Papaya cultivars **-** Solo and Washington are resistant against *R. reniformis* while cv. Coorg Honey Dew has moderate resistant **-** reaction.
- Papaya cultivars Co-2 and Co -3 inhibits development and reproduction of *M. incognita* (Naik, 1986).

5. Biological control

- Application of *Paecilomyces lilacinus* and or *Trichoderma harzianum* @ 0.5 and 1.0 g fungus mycelium / plant improved papaya growth and reduced the number of galls (Khan, 1991).

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Eerspectives i Eost Harvest Ha dli g o(7ruits

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India is blessed with a variety of the agro-climatic conditions, favouring the production of a wide range of tropical, subtropical, temperate, and arid zone fruits. With the adoption of advanced technologies and increased area, in terms of production, it has gained the first position in the world, with a production of 40 million tonnes of fruits grown in 3.6 million hectares with an average productivity of 10.88 t/ha. India is the largest producer of banana (10.32 MT), mango (10.16 MT) followed by citrus, guava, papaya, apple, grape, pineapple, sapota, litchi etc.

Rapid strides are made for enhanced production and increasing the under area cultivation. However, no systematic arrangements have been made so far for the suitable post-harvest handling of the produce, resulting in 20 to 30% postharvest losses. This is mainly due to lack of proper infrastructure facilities, like packing houses for sorting, grading and packing of the harvested produce, non-availability of the commercial cold stores maintained at varied low temperatures, lack of the cool chain during transport and storage, depending on the nature of fruit as some of the fruits are highly perishable than the others. The losses vary from 17 to 36% in mango, 12 to 14% in banana, 8 to 30% in oranges, 10 to 25% in apples, 3 to 15% in guava, 5 to 20% in pineapple, and 23 to 30 % in grapes (Madan and Ullasa, 1993). These losses vary among the cultivars of the same fruit and it occurs at the farm level (harvesting), grading, transport, storage, and marketing. Control of these losses alone may contribute a lot for increasing the availability of fruits for the common man. Reduction of these losses both qualitatively and quantitatively could be achieved by proper harvesting methods, harvesting of the fruits at an optimum maturity, ripening, sorting, grading and suitable packing of the graded fruits, pre-cooling of the fruits prior to the storage, adoption of the refrigerated transport and storage under controlled conditions, pre- and post-harvest treatments and proper marketing procedures.

Post-harvest management and the value addition

In the recent past, the postharvest management of fruits has received greater attention. Some of the significant developments are use of the corrugated fibre board (CFB) boxes, pre treatment, pre-cooling and development of cool chain and cold storage facilities etc., for fruits. The working group on Agricultural Research and Education for the IX plan has reemphasized on the postharvest management of the horticultural crops, particularly for reducing the losses of the perishables and making the handling more cost effective.

Presently, value addition is being done in fruits like mango, grape, litchi and apple through proper grading and packaging. Certain processed products like jam, jelly, pickles, packed beverages and others are marketed using different fruits as raw materials. New products, which require to be exploited, are the fruit juice concentrates, cryogenically frozen slices and asceptically packed fruit pulp. There is vast scope for the diversification and the development of the new products from ber, bael, pomegranate, and litchi etc. keeping in view of the strength of the ICAR institutes with its multidisciplinary team of the scientists and the urgent needs of the technology.

To reduce the postharvest losses as well as the value addition, the following are advocated as constraints for the postharvest management research.

- Screening of the germplasm and the varieties for processing and diversified use including export promotion.
- Farm gate storage and the primary processing to reduce the postharvest losses and to avoid the market gluts.
- Grading, pre treatments, packaging, transportation, and enhancement of the shelf life of the fruits.

- Market development and the value addition of the produce through proper pre- harvest crop management, maturity standards, harvesting and the chemical treatments to enhance the post harvest life.
- Pilot scale testing of the technologies developed earlier for the commercial adoption.

Indices of maturity

The definition of maturity as the stage of development giving minimum acceptable quality to the ultimate consumer implies a measurable point in the commodity's development, and the need for techniques to measure maturity. The maturity index for a commodity is a measurement or measurements that can be used to determine whether a particular example of the commodity is mature. These indices are important to the trade in fresh fruits for several reasons (Reid, 1985).

In most markets the laws of supply and demand and meanprice incentives for the earliest (or sometimes the latest) shipments of any particular commodity encourages growers and shippers to espedite (or delay) the harvesting of their crop to take advantage of premium prices. The minimum maturity statements in the grade standards are placed there to prevent sale of immature or over mature product and consequent loss of consumer confidence. Objective maturity indices enable growers to know whether their commodity can be harvested when the market is buoyant.

Efficient use of labour resources

In many crops, the need for labour and equipment for harvesting and handling is seasonal. In order to plan operations efficiently, growers need to predict the likely starting and finishing dates for harvest of each commodity. Objective maturity indices are vital for accurate prediction of harvest dates.

Characteristics of a maturity index

Maturity measures made by producers, handlers and quality control personnel must be simple, readily performed in the field or orchard and should require relatively inexpensive equipment. The index should preferably be objective (a measurement) rather than subjective (an evaluation). The index must consistently relate to the quality and postharvest life of the commodity for all growers, districts and years. If possible, the index should be non-destructive. The search for an objective determination of maturity has occupied the attention of many horticulturists, working with a wide range of commodities for years. The number of satisfactory indices that have been suggested is nevertheless rather small and for most commodities the search for a satisfactory maturity index continues.

Ripening

Some of the fruits harvested at mature stage viz., mango, banana, papaya, sapota, custard apple etc., have to be ripened under ambient conditions to get a good quality edible ripe fruit. This ripening process involves a series of metabolic activities. There is an increase in the respiration rate of the fruits, conversion of starch to the sugars, reduction in the acidity, removal of the astringency or tart taste, softening of the fruit, development of a characteristic aroma and colour of skin as well as pulp. Ethylene is released during respiration. In some fruits like grapes, litchi, pineapple, strawberry, plum etc., which are harvested at ready to eat stage, these changes are not significant.

For the commercial ripening of banana, smoking has been adopted traditionally, but it is being replaced with the use of ethylene gas released by ethrel, a chemical available commercially. It may be used to hasten the ripening of fruits without any undesirable changes in quality. For ripening of mango throughout the country, calcium carbide is being used, which results in a poor taste of the fruits. This is because immature mango fruits are harvested and treated with calcium carbide to get a good price early in the season. In fact, as per the prevention of food adulteration act, 1955, rule 44 AA, use of calcium carbide for ripening is banned by the Govt. of India. The adverse effect of this chemical on the taste of ripe fruit is more in acidic varieties like Alphonso and Raspuri. Hot water treatment of the mangoes at 52 to 55°C for 5 min has been recommended for uniform ripening, which also reduces the spoilage by more than 50 per cent.

Postproduction residue analysis on fruits

Fungicides are recommended to be used mainly on fruits to control various diseases and reduce postharvest losses. The pesticides most commonly used for postharvest treatments are thiophanate methyl, carbendazim, benomyl, prochloraz, captan and dimethoate. It is imperative that the safety of such treatments being established on the basis of residues at the time of consumption. It was seen that when mango fruits were dipped for 5 min in carbendazim (9500 ppm) or captan (1000 ppm) solution, the residues persisted only for 10 days, however the same were above permissible level in case of carbendazim. Post harvest dip treatment with carbendazim, therefore cannot be recommended for mango.

To reduce the risks arising out of indiscriminate use of pesticides,

1. Only need based application of pesticides should be given.
2. There should be increase in the pace of IPM adoption especially in fruits.
3. Soil and water systems having excess residue problem should be mapped.

The following are the criteria for judging maturity in fruits:

Elapsed days from full bloom to harvest, mean heat units during development, development of abscission layer, surface morphology and structure, size, specific gravity, shape, textural properties, firmness, external colour, internal colour and structure, compositional factors, total solids, starch content, sugar content, acid content, sugar / acid ratio, juice content, oil content, astringency (tannin content), internal ethylene concentration.

Mechanical harvesting

Mechanical harvest is not presently used for most of the fresh market crops because machines are rarely capable of selective harvest, they often cause excessive product damage and they are expensive. Commodities that can be harvested at one time and are less sensitive to mechanical injury (nuts) are amenable to mechanical harvesting. Rapid processing after harvest will minimize the effects of mechanical injury.

Primary advantages:

1. The potential for rapid harvest is available.
2. Working conditions are improved.
3. Problems associated with hiring and managing hand labour are reduced.

Effective use of mechanical harvesters requires operation by dependable, well trained people. Improper operation results in costly damage to expensive machinery and can quickly cause great crop damage. Both regular and emergency maintenance must be available. The commodity must be grown to accept mechanical harvest. For example, trees must be pruned for strength and to minimize fruit damage caused by fruit falling through the tree canopy.

Mechanical harvest problems

1. Damage can occur to perennial crops (e.g. bark damage from a tree shaker)
2. Processing and handling capacity may not be able to handle the high rate of harvest.
3. Equipment may become obsolescent before it is paid for.
4. There are social impacts to lower labour requirements.

Mechanical harvesting of crops, now hand-harvested will probably require breeding new varieties that are more suited to mechanical harvest. This lengthy process has been done for only a few crops. Equipment has been developed for the easiest crops to harvest mechanically (ASAE, 1983). Other crops will be mechanized at a slow rate compared with the rate of mechanization over the past 40 years.

Grading

Considerable variation exists in the quality of harvested fruit due to genetical, environmental and agronomic factors and therefore, requires grading to get suitable returns. Proper grading facilities are lacking, which are required for the effective marketing of fruits through the removal of various mal-adjustments prevailing in the existing agriculture marketing system.

In India, fruits are graded on the compulsory basis for the export and voluntary basis for the internal marketing. At present, fruits are mainly graded at the producer's level in regulated markets of different states. The process of grading of fruits in the country has not progressed much due to poor legislative and financial support and the lack of effective extension services for the dissemination of improved post harvest technologies of fruits. At present, mangoes are graded by their weight and colour, citrus based on the skin colour, shape, size and bananas by the number of hands per bunch.

Presently grading standards are available for a few fruits only and there is a need to frame grading standards for all the fruits. Proper understanding and co-ordination between different organizations dealing in horticultural crops, studying operating models of the quality control organization and grading followed in other countries such as EEC and USA, co-operatives like NDDB, fresh marketing co operative society, Hyderabad and HOPCOMS, Bangalore could play a vital role in promoting the grading activity of fruits at the producer's level.

Packaging

Packaging is a fundamental tool for the postharvest management of highly perishable commodities like fruits. The present packaging and distribution system for fresh fruits still depends on the traditional forms of packages, like bamboo baskets, wooden boxes and gunny bags. The use of baskets besides being unhygienic prevents convenient handling and stacking and it also reduces the efficiency of capacity utilization in transport system. Wooden packages are not conducive for the packaging of fresh fruits, as they occupy unnecessary additional volume and contribute to the additional tare weight. Furthermore, continuous use of the wooden cases in packing of the apples in hill regions has resulted in deforestation. Therefore, the use of alternative packages like corrugated fiber board boxes, woven sacks, molded pulp trays, re-usable plastic containers have to be encouraged (Shantha Krishnamurthy and Sudhakar Rao, 2001).

Storage

Proper storage of fresh fruits for extended periods is very much essential for the proper utilization of fruit in the glut period. In tropical climate, with a high temperature and humid weather, the storability of fruits is very much reduced with heavy losses. At present, there are about 3,443 cool store units with a total cold storage capacity of around 30 million cubic meters capable of storing 10 million tonnes of the primary produce (Negi, 2000). Around 90 % of the cold store capacity is utilized for the storage of potatoes only. Fruits and vegetables together utilize only a meager 8.56% of the total cold storage capacity. There is growing demand for the new cold storage units due to steady increase in the production of fruits every year.

Concept of cold chain

Establishment of a cold chain is very much essential for the effective preservation of quality of fresh fruits from harvesting to final consumption. It is essential to have refrigerated transport from the farm to the pack house, where it has to be graded, packed and pre-cooled to an optimum storage temperature. The pre-cooled produce has to be shifted in refrigerated trucks to the cold storage for long term storage or to the wholesale centres must have cold storage facilities either individually or collectively. This has to be disposed of to the retailers or super markets with low temperature storage facilities. This type of cold chain linkage helps in introducing a systematic approach and it results in reducing the wastage at farm level, transport and storage. At present, the cold chain concept is in operation to some extent for the export of mangoes and grapes with encouraging results.

Transport

Depending on the distance to be covered, fruits are carried as head loads, on the back of animals, carts, trucks and train. Road transport by trucks is faster and it is preferred as train transport has not proved beneficial, because of the lack of ventilated wooden or air cooled wagons, which are also not filter proof. Existing unventilated steel wagons build up more heat (40 to 50 °C) causing more loss. Bulk transport is still by the free loads only. Among different types of the containers shallow plastic crates were found to be better during transportation of fruits from the field to the pack house or to the local market to prevent bruising losses.

Export promotion of fruits

Certain impediments limiting the exports of the horticultural products from India include the lack of the suitable varieties in some of the fruits to meet the specific market demands, insufficient production, low productivity resulting in a high cost of production, lack of emphasis on the quality improvement of the produce, poor post harvest management and lack of the infrastructure facilities. At present our exports of the fruits are restricted mainly to the mango, grape, cashew nut, while certain other fruits like pomegranate, sapota, banana, litchi, apple and strawberry have also entered the fresh fruit export markets in limited qualities.

The following researchable issues have been identified for the rapid export promotion of the fruits from India.

- Develop bulk handling system for the tropical fruits, including pre-cooling and CA/ MA storage.
- Post harvest protocols for the sea transport of major fruits, like banana, mango, litchi, sapota, kinnow mandarin, pomegranate and others.
- Disinfestations technology and the response of the vapour heat treatment (VHT) for the export of the fresh fruits.

- Organic farming and residue free integrated pest management (IPM) technology.

The following production issues are the main constraints for post harvest and value addition of fruit crops. In spite of impressive achievements, a lot is required to be done.

- A sizeable area in the country is barren or does not yield a desired level of the productivity. Since, India's land base is shrinking day by day; fruit cultivation has to be done in problem soils. Therefore, it is necessary to discuss techniques of fruit production in such soils. Orchard soil management practices, such as cover crops, inter-crops, mulches, sod culture, weed control and clean cultivation have a profound effect on the productivity, which needs to be understood.
- In addition to the present day constraints like shortage of the suitable land, high management costs, restriction on water use, labour problems, and necessity of early returns on the investment have made it necessary to think in terms of the maximum possible returns with the minimum cost in the shortest possible time. This emphasizes the need for high density plantings in future fruit plantations.
- Canopy management is also assuming importance to ensure better use of the land and climatic factors to increase the productivity per unit area.
- Integrated nutrient management (INM), which should be economically viable, environment friendly and socially acceptable, is another important aspect of the fruit production.
- Use of the leaf analysis as a guide for the nutrient management of fruit crops is based on the premise that the crop behaviour is directly related to the concentration of nutrients in the index tissue.
- Crop regulation is another operation, which aims to regulate a uniform and good quality fruits.
- Attempts have to be continued with the use of bio-regulators to manipulate the growth and development processes in fruit crops to streamline the production.
- Although, mango malformation and guava wilt were first reported in 1981 and 1935 respectively, limited progress has been made for the management of these diseases. Efforts to control such complex disorders need to be intensified. A comprehensive interaction needs to be planned to give ample scope to the scientists to solve these problems.

While, India has a good natural resource base with large fruit production, the postharvest scenario of fruit crops is not much encouraging. A large quantity of the fruit goes waste due to lack of adequate storage facilities. There is an urgent need to look more closely at some basic aspects of postharvest management of the fruits. There is need to develop new products from arid and semi arid fruits and popularizes them not only in domestic market but also in international markets. Efficient disposal and recycling of fruit wastes, which may be a source of atmospheric pollution and contamination, would provide vital nutritional components to our foods and bring down the cost of production of processed foods besides minimizing the pollution hazards.

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Bioi (ormatics

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Bioinformatics is the confluence of two trends in modern science and technology. The first is that advances in molecular biology, i.e., genome sequencing, analysis of the sequence and structure of nucleic acids and proteins which have provided a wealth of new data that is truly staggering and completely beyond manual methods of comprehending and analyzing. The second trend is the communication revolution spearheaded by the computers connected to the Internet. Today's personal computers are powerful enough to use in meaningful research, embodying the power of the supercomputers of only a few years earlier, facilitated by the collaborative computing through millions of computers connected to the Internet. This has created a gene revolution of the mouse click kind that lead to the abundance of gene and proteins sequence data, with free tools to use them, available on the net on one side and millions of researchers and commercial R and D establishments scrambling to get a slice of the web of information on the other side. The latter group also contribute to the web of biotechnological information when they get some significant results. Thus a public domain of collective knowledge of thinking people world over is available on the net, which may lead to a new world order of knowledge.

Just because so much is available on the net, one starts thinking that bioinformatics is doing an Internet search with google or yahoo. But it's on the contrary. Biological information like gene and protein sequence databases is available in the public domain. So also tools to access and manipulate them. But how to access and what to do when you access these resources are completely left to the researcher attempting it. One must be master of all, especially of genetics and computer, besides a wizard of a specific field to work with. Such is the abundance of bioinformatics. Then, what is bioinformatics and what are the resources?

What is bioinformatics ?

Bioinformatics is an integration of mathematical, statistical and computer methods to analyze biological, biochemical and biophysical data.

Is this the only definition of Bioinformatics? Absolutely not. Bioinformatics is a bright new field. This is exemplified in the lack of a standard definition for the word. Here is a sampling of definitions that were found after a simple web search. All certainly have a high degree of validity.

Bioinformatics : The science of developing computer databases and algorithms for the purpose of speeding up and enhancing biological research. Bioinformatics is being used most noticeably in the Human Genome Project, the effort to identify the 80,000 genes in human DNA. New academic programs are training students in bioinformatics by providing them with backgrounds in molecular biology and in computer science, including database design and analytical approaches. (Definition from Whatis.com)

Bioinformatics : a combination of Computer Science, Information Technology and Genetics to determine and analyze genetic information. (Definition from BitsJournal.com)

Bioinformatics : is the science and technology about learning, managing and processing biological information. (Definition from Missouri University lecture).

(*Molecular*) **bio-informatics** : bioinformatics is conceptualizing biology in terms of molecules (in the sense of Physical chemistry) and applying "**informatics techniques**" (derived from disciplines such as applied maths, computer science and statistics) to understand and organize the information associated with these molecules, on a **large scale**. In short, bioinformatics is a management information system for molecular biology and has many **practical applications**. This is the definition as submitted to the Oxford English Dictionary during 2001.

And although the term 'Bioinformatics' is not really well-defined, you could say that this scientific field deals with the computational management of all kinds of biological information, whether it may be about genes and their products, whole organisms or even ecological systems. Most of the bioinformatics work that is being done deals can be described as analyzing biological data, although a growing number of projects deal with the organization of biological information. As a consequence of the large amount of data produced in the field of molecular biology, most of the current bioinformatics projects deal with structural and functional aspects of genes and proteins.

The Scientific American described that there is going to be a mad goldrush for Bioinformatics by the scientific as well as business community. All this started as bioinforming, i.e., merely documenting the voluminous DNA and protein sequence data involving advances in information technology, thus benefiting the IT business which in turn has created hype of unprecedented scale about bioinformatics. This hype has created great enthusiasm among the researchers and business, especially those in pharma industry that has lead to the biopharming. Now, a lot of pharma companies are using bioinformatics in their drug discovery programs. Well, is there anything in this for biofarming (the crop industry)? Yes, the future of bioinformatics is in the hands of crop science. Thousands of crop species may produce abundance of sequence data. If this ocean of data is mined through the use of vast computing power, functions for sequences can be predicted. That's what is functional genomics. That's where lies the true magnitude of bioinformatics in crop sciences, in areas like breeding for stresses, post-harvest life of fruits and vegetables, vasel-life of flowers, pest/disease resistance, exotic combinations in ornamentals, forever flowers and so on.

You have to sail to test the waters. So let's have an understanding of the field of bioinformatics by a brief overview and start using the tools available in the public domain.

Bioinformatics resources

Since bioinformatics is a marriage of computer and biology, it is not surprising that it is well kept abreast with advances in computer technology, in particular, the internet technology. The internet came into being about twenty years ago as a successor to ARPANET, a US military network disguised to provide networking capabilities with a high redundancy. The principle behind has remained unchanged and has proven very powerful : to have every computer potentially talk to each other, regardless of what platform, what network path the communication actually takes.

By going cybernized, information and knowledge disseminate at a much more timely rate. There are countless electronic publications on the net. These publications appear in the form of regular ascii text, poscript, hypertext, java and other derivations there from. The resources available on the net for the biologists are listed below :

I. Bioinformatic Databases

Bioinformatic databases are electronic reservoirs of biological data. Here are a few types and examples of these databases :

Nucleotide sequence databases

GenBank, EMBL (**E**uropean **M**olecular **B**iology **L**aboratory) and DDBJ (DNA Databank of Japan)

- Updated and maintained on a daily basis
- All EMBL and DDBJ entries are contained in GenBank
- You can submit entries to GenBank using the program Sequin.

Protein sequence databases

SwissProt (sequence search SwissProt), PIR (Protein Information Resources) : updated and maintained on a daily basis.

3D Structure Database

PDB (Protein Database), Eukaryotic promoter database : EPD

Database of Expressed Sequence Tags (EST) : dbEST

- Contains partial nucleotide sequences (generally single sequencing runs from both ends of the insert) of randomly picked cDNAs from different tissue libraries; EST entries are submitted from a wide variety of organisms and many represent novel genes.

Other Databases

- **Entrez** is a retrieval system for searching several linked databases, these arealist of databases that can be searched using Entrez.

II. Bioinformatics tools

A. Sequence similarity searching tools

1. Local Alignment Methods (BLAST)

BLAST (Basic Local Alignment Search Tool) : Blast programs use a heuristic search algorithm. The programs use the statistical methods of Karlin and Altschul. BLAST programs were designed for fast database searching, with minimal sacri.ce of sensitivity for distantly related sequences. The programs search databases in a special compressed format. It is possible to use one's private database with BLAST. To this it is required to convert it to the BLAST format.

- Allows the user to identify similarities between the query nucleotide or protein sequence with sequences in public databases.
- Identifies clusters of nearby or locally dense "similar" **k-tuples** (number of string of letters)
- Used to identify whether a given sequence is novel, homologous to a known sequence, or if the sequence contains motifs which may provide clues to a possible roles of the sequence being queried.
- Most commonly used tools at the NCBI (National Centre for Biotechnology Information).

BLAST Programmes : each BLAST program performs a different task :

blastp compares an amino acid query sequence against a protein sequence database

blastn compares a nucleotide query sequence against a nucleotide sequence database

blastx compares a nucleotide query sequence translated in all reading frames against a protein sequence database.

tblastn compares a protein query sequence against a nucleotide sequence database dynamically translated in a reading frames

tblastx compares the six-frame translations of a nucleotide query sequence against the six-frame translocations of a nucleotide sequence database.

How Do You (Use) BLAST?

Sequence Input

The preferred query sequence format for the BLAST program is the **FASTA format**. Advanced BLAST tolerates both spaces and numbers and is case insensitive.

Parameter settings

Parameter settings can be modified to optimize your BLAST search :

- **Sequence filtering** : enables the program to mask regions of a query sequence in order to exclude regions of low compositional complexity such as repetitive elements (turned ON as the default setting) it inserts "x"s in regions of low complexity.
- **Introduction of gaps** : (regions of insertions and deletions); blastn and blastp search tools offer fully gapped alignments, while blastx and tblastn have "in-frame" gapped alignments; the tblastx search tool provides only ungapped alignments (turn ON as the default setting).
- **Statistical matrices** : are used both to identify sequences in a database, and to predict the biological significance of the match. There are two main types of matrices, you can select the preferred matrix for your Advanced BLAST search
- **PAM (Percent Accepted Mutation) matrices** : predicted matrices, most sensitive for alignments of sequences with *evolutionary related homologs*. The greater the number in the matrix name, the greater the expected evolutionary (mutational) distance, i.e., PAM30 would be used for alignments expected to be more closely related in evolution than an alignment performed using the PAM250 matrix.
- **BLOSUM (Blocks Substitution Matrix)** : calculated matrices, most sensitive for *local alignment of related sequences*, ideal when trying to identify an unknown nucleotide sequence. BLOSUM62 is the default matrix set be the BLAST search tool.

Results Format

- Results returned in either text format (default) or HTML format (must supply an e-mail address and select the HTML results format option)
- A request ID number is given such that the results be obtained at a later time, if you want the results immediately, click on the "Format Results" button.

- Formatting items such as the results format option and the number of descriptions and alignments in the results output are needed only for formatting, these items may be specified from the BLAST query form or at the time you request your results
- Most results will be help for up to 24 hours; very large results files will be deleted after 30 minutes

BLAST Output

All BLAST programs produce a similar output consisting of :

- Program introduction
- A schematic distribution of the ordered alignments of the query sequence to those in the databases
- Coloured bars are distributed in a way to reflect the region of alignment onto the query sequence. The colour legend represents the significance of the alignment scores
- Holding the mouse over a given bar will display a description of that specific alignment sequence in the above window; clicking on a specific bar will cause the browser to jump down to that particular alignment.
- An ordered set of biological definition line of the database sequences which have been significantly aligned to the query sequence.
- Sequence alignments and their corresponding line descriptions are listed in order of lowest to highest E value.
- **E value** : the expect value is the probability that the associated match is due to randomness; the lower the E value, the more specific / significant the match.
- Identifiers for the database sequences appear in the first column and are hyperlinked to the associated GenBank entry.
- **The Score** (bits) is a sum value calculated for alignments using the scoring matrix, the higher the score value, the better the alignment.
- The per cent identify (called "Identities" is given as a per cent) is the per cent of exact matches between your query sequence and the database sequence, this value also gives the number of nucleotide bases or amino acid residues that are matched in the database sequence versus the query sequence.
- Alignments are listed in order of lowest to highest E value (as are the descriptions)
- Alignments are gapped unless specified by the user at the BLAST search submission page
- **Gap value** is the per cent of the alignment sequence that has been gapped in the particular alignment.

BLAST now comes in several flavours. It includes,

MEGABLAST search : like a Basic BLAST search, but allows you to change certain parameters in order to perform a more specified BLAST search.

- Specify an organism or taxonomic class for your search
- Set the E value
- Filter for low complexity or human repeats
- Query Genetic Codes (blastx and tblastx only)
- Change you scoring matrix (BLOSUM62 is the default scoring matrix)
- There are other advanced BLAST options.

PSI-BLAST (Position Specific Iterated-BLAST)

- This tool can be used when your BLAST search results give you very few matches, the PSI-BLAST will re-iterated the BLAST searches creating a defined profile, upon re-iteration (you just click on the button to re-iterate) you may reveal alignment matches that are significant that you would not have found using BLAST alone. PSI-BLAST generates "on-the-fly" a scoring matrix specific to your BLAST search, and continues to specify this matrix upon each re-iteration.

PHI-BLAST: (Pattern Hit Initiated-BLAST)

- This tool can be used to search for a specific pattern or motif in you sequence and in the databases
- The pattern designates the amino acid sequence you are searching for e.g. [RG]-[M]-[X]-[YWF]-5[X]-[A]; this submission pattern would yield a search for sequence patterns having "R" (Arginine) or "G" (Glycine) at position 1 (not necessarily position 1 or the N-terminus of the amino acid sequences in the databases) followed by a "M" (Methionine), followed by any amino acid "X", followed by any one of three AA : "Y"

(Tyrosine) or "W" (Tryptophan) or "F" (Phenylalanine; followed by any 5 amino acids "X", followed by an "A" (Alanine).

BLAST 2 Sequences

- This tool produces the alignment of two given sequences using BLAST engine for local alignment.

GENERAL GUIDELINES for analysis CUT-OFFS of BLAST OUTPUT

- E-value < 0.05
- % identify >25% over 100 base pairs or 35 amino acid residues

2. Global Alignment : FASTA

- identifies clusters of nearby or locally dense "identical" k-tuples, takes this local alignment and extends it globally
- decreases the sensitivity, but gains speed
- Z-score : number of S.D. above the random
- Default matrix : BLOSUM50
- Output : local alignment score, global score, maximum score, E-values as well as alignments and descriptions

B. Gene Analysis Tools

ORF Finder

Open Reading Frame (ORF) Finder tool identifies all possible ORFs in a DNA sequence by locating the standard and alternative stop codons in all six reading frames of the corresponding translated amino acid sequence. The ORFs are represented as shaded boxes. By clicking on a shaded box, the amino acid sequence of that ORF is displayed. The deduced amino acid sequences can then be automatically used to BLAST against GenBank sequences.

Genscan

The GENSCAN program is a gene-hunter, it predicts the exon/intron boundaries of a sequence as well as the 5' and 3' UTR sequences and poly-A tail sequences. GENSCAN claims an ***accuracy of 80%*** in its predictions using human/vertebrate sequences.

HMMgene

HMMgene is a program for prediction of genes in anonymous DNA. The program predicts whole genes, so the predicted exons always splice correctly. It can predict several whole or partial genes in one sequence, so it can be used on whole cosmids or even longer sequences. HMMgene can also be used to predict splice sites and start/stop codons. If some features of a sequence are known, such as hits to ESTs, proteins, or repeat elements, these regions can be locked as coding or non-coding and then the program will find the best gene structure under these constraits. HMMgene takes an input file with one or more DNA sequences in FASTA format. It also has a few options for changing the default behaviour of the program.

The output is a prediction of partial or complete genes in the sequences, you can increase the number of best predictions (1-5 best predictions). The output is in a standardized format that is easily read by other programs, which specifies the location of all the predicted genes and their coding regions and scores for whole genes as well as exon scores.

C. Domain Search Tools

CD-Search

The new CD-Search (Conserved Domains – Search) tool is available from the NCBI BLAST home page, it is a service that employs a reverse position-specific BLAST algorithm to compare the query sequence to a position-specific score matrix prepared from the underlying conserved domain alignment. The CDD (**C**onserved **D**omain **D**atabase) contains domains derived from two popular collections, Smart and Pfam, plus contributions from colleagues at NCBI. The CD-Search service may be used to identify the conserved domains present in a protein sequences. Hits may be displayed as a pairwise alignment of the query sequence with a representative domain sequence, or as a multiple sequence alignment.

D. Multiple Alignment Tools

ClustalW

ClustalW is a multiple sequence alignment tool

- **Input formats** : FASTA, NBRF/PIR, EMBL/SwissProt, GDE, Clustal, GCG/MSF, RSF. Remove any white space or empty lines from the beginning of your input.
- **Results** : You may choose between email (default) and interactive runs.
- **Alignment** : you may choose to run a full alignment or using a stringent algorithm for generating the tree guide or a fast algorithm.

- **Output** : options of output are ALN, GCG, PHYLIP, PIR and GDE. You may have colour alignments.

Types of alignments

- Fast Pair wise Alignment Options
  - KTUP : allows you to choose a 'word length'
  - WINDOW : you may set the window length
  - SCORE : allows you to specify a score threshold
  - PAIRGAP : you may set the gap penalty
- Multiple sequence alignment options
  - MATRIX : allows you to choose which matrix series to use
  - BLOSUM (appear to be the best available for carrying out homology searches). BLOSUM80, 62, 40 and 30 matrices are used
  - PAM : extremely widely used, PAM 120, 160, 250 and 350 matrices
  - GAPOPEN : you can set here the penalty for opening a gap
  - ENDGAP : you can set here the penalty for closing a gap
  - GAPEXT : you can set here the penalty for extending a gap
  - GAPDIST : you can set here the gap separation penalty

Multalign

Multalign is another multiple sequence alignment tool. An algorithm is presented for the multiple alignment of sequences, either proteins or nucleic acids, that is both accurate and easy to use. The approach is based on the conventional dynamic-programming method of pair wise alignment. Initially, a hierarchical clustering of the sequences is performed using the matrix of the pair wise alignment scores. The closest sequences are aligned creating groups of aligned sequences. Then close groups are aligned until all sequences are aligned in one group. The pair wise alignments included in the multiple alignment form a new matrix that is used to produce a hierarchical clustering. If it is different from the first one, iteration of the process can be performed.

E. Other Tools

VAST

VAST search is a structure-structure similarity search service. It compares 3D coordinates of a newly determined protein structure to those in the MMDB/PDB database. VAST Search computes a list of similar structures that can be browsed interactively, using molecular graphics to view super impositions and alignments.

UniGene

UniGene clusters repeated EST entries which represent the same gene. This database is also valuable for researchers looking for tissue-specific cDNAs because UniGene can list clusters containing ESTs found in only one tissue library.

VecScreen

VecScreen is a tool for identifying segments of a nucleic acid sequence that may be of vector, linker or adapter origin prior to sequence analysis or submission. VecScreen was developed to combat the problem of vector contamination in public sequence databases.

Electronic PCR

The Electronic PCR feature allows you to search your DNA sequence for the presence of sequence tagged sites (STS), which have been used as landmarks in various types of genomic maps. The default is to search all STSs, but searches may be restricted to one organism by selecting it from the list below the input box. You may either enter sequences (in FASTA format) or enter GenBank accession numbers into the text box.

What's in there for horticulture?

In horticultural industry, increasing crop production and quality rely heavily on identification of new plant traits that can be incorporated into new plant varieties by breeding program. Genomics is aiding plant biotech industries in accelerating the crop improvement by rapid identification and manipulation of new traits. The same techniques of high throughput sequencing and expression and functional analysis that facilitated the discovery of new drug targets in pharmaceutical industry are playing a major role. In many plants like corn and tulip, as gene density per megabase of DNA is low, large scale EST sequencing may be the way to go.

Sequence databases in horticulture

CassavaDB, BeanGEnes, EthnobotDB (*world wide plant uses*), MPNADB (*Medicinal plants*), PhytochemDB (*Plant Chemicals*), RoseDB (*Malus, Prunus,* etc.), SolGenes (*Lycopersicon, Solanum,* etc.), CoolGenes (*Cool Season food legumes*), Ecosys (*Plant ecological ranges*), FoodplantDB (*Food plants*), PhytochemDB – (*Plant chemicals*)

Some applications in horticulture

- Forever Flowers – Ethylene control utilizing ERT1-1 gene
- Post-harvest life in fruits, vegetables and flowers through ethylene control
- Molecular engineering on medicinal herbs to improve the production of useful phytomedicines
- Manipulate light controlling genes in plants through a functional genomics approach.
- Discovery of useful plant genes for phytoremediation of heavy metals pollution transformation of garlic, vegetative propagation (pollination is not possible in garlic)
- Antibiotic resistant genes
- Herbicide resistant genes
- Virus resistance
- LUCIFERASE gene in Cactus that glow in the night
- RESISTANCE MANAGEMENT IN PLANTS
- Dow Agro Sciences – SPINOSAD – from Actinomycete *Saccharapolyspora spinosa* – Biopesticide – reduced risk, wide range, organic standards
- Genomics of plant root systems – Echinacea and Diascorea – Role in immune modulations
- DNA chips for gene identification in tomato roots and comparison
- Genomic analysis of root system under abiotic stresses.
- Functional genomics of secondary metabolites in two herbal plants – Echinacea and Dioscorea

Where do you start ?

On the Internet, type "bioinformatics" in the search engine (www.google.com or www.yahoo.com) and follow the links. And I am not concluding, as it's just the beginning.

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