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Modern systems of fruit growing and their application for the improvement of tropical fruit production

Shafaat Mohammed and Lawrence A. Wilson

Department of Crop Science, University of the West Indies, St Augustine, Trinidad

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Modern fruit growing systems such as Bush Orchard. Meadow Orchard, the Tatura Trellis, Pyramid. Cordon. Curtain and the Hedgerow are described. A comparison is drawn between the modem systems and the traditional system of fruit growing. In addition to early cropping and returns on investment, high regular yields and low labour requirement, the modern systems of fruit growing offer several advantages over the traditional system. The feasibility of applying these new systems of fruit growing for the improvement of tropical fruit production (with special reference to the research at the University of the West Indies into the development of the Meadow Orchard system for guava production) is mentioned.

Keywords: Fruit; Production; Growing systems

Modern systems of fruit growing which have been developed over the years for temperate fruit production (Fig. 1) can be employed for tropical fruit production with certain modifications. These systems basically involve the planting of small trees densely. controlling growth by chemicals, dwarfing rootstocks, pruning and training; and, in some cases, harvesting by machine. This development in the area of horticulture took place gradually from relatively few large trees per hectare grown on seedling rootstocks through many intermediate forms to high density planting systems with many pindle-type trees per hectare on dwarfing root-stocks. The reason for this change was the necessity to achieve early cropping, high regular yields and low labour requirement to meet continually rising production costs. Comparisons between these modern systems and the traditional systems of fruit growing indicate that the former systems offer several advantages over the latter (Table 1). Moreover, the few disadvantages of modern systems of fruit growing may be solved by research.

Although modern systems of fruit growing have become popular and are being used on commercial scales for temperate fruit production, their potential and usefulness in the field of tropical fruit production still remain unexploited. At the same time, the traditional system of fruit growing is proving to be inefficient, unattractive and unmanageable and is contributing to a decline in tropical fruit production, particularly in areas of high labour cost.

There is urgent need for improving and modernizing the traditional system of tropical fruit growing. This Paper describes various modern systems of temperate fruit growing and examines the feasibility of utilizing such systems in the improvement of tropical fruit production.

Classification

The modern systems of fruit growing described here could be classified (Fig. 1) on the basis of density or intensity of planting, as medium high density planting (mhdp), optimum high density planting (ohdp), and maximum or ultra-high density planting (uhdp). However, classification of these systems on the basis of shape, size and form of trees such as Bush, the Tatura Trellis, Pyramid, Cordon, Curtain, Hedgerow (fruit wall or tree wall) and Meadow Orchard seems

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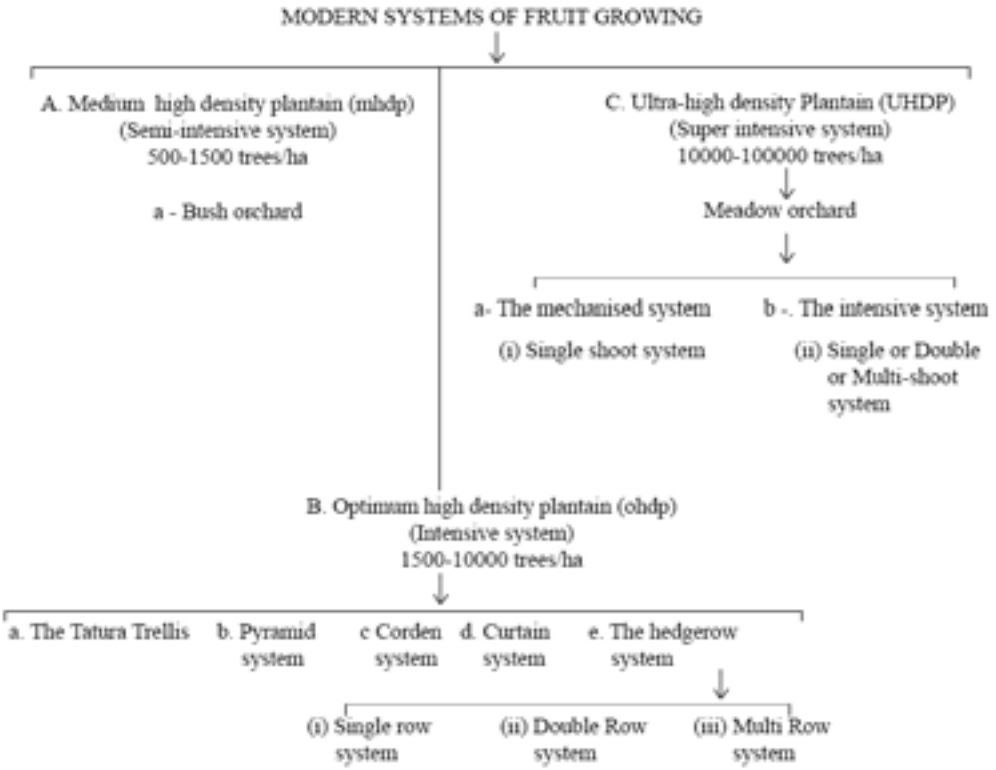

Fig. 1 Schematic illustration of various modern systems of fruit growing

Table 1 Comparisons between traditional systems and modern systems of fruit growing

Attribute	Traditional systems	Modern systems
Tree number	Few large trees ha^{-1} (≈ 150–200 trees ha^{-1})	Many small trees ha^{-1} (≈ 500–100 000 trees ha^{-1})
Bearing	Late in bearing: usual time required is 6–8 years or more	Precocious in bearing: usual time required is 2–3 years
Production	Overall production per hectare is low (≈ 15–25 t ha^{-1})	Increased overall production per hectare (≈ 30–50 t ha^{-1})
Management	Difficult to manage due to large size of trees	Easy to manage small trees
Labour	Requires more labour	Requires less labour
Production cost	Higher cost of production	Reduced cost of production
Harvesting	Difficult (Manual)	Easy by machine
Quality	Large canopy, poor sunlight penetration and poor quality	Small canopy, better sunlight penetration and a better quality
Establishment cost	Low	High
Machinery	Does not require expensive machines	Requires expensive machines
Chemical or growth substance	Not essential to use growth substances to control growth, flowering and fruiting	Requires the use of growth substances for control of flowering and fruiting

to be more common. This latter classification is used here, but reference is also made to plant density in the description of systems of fruit growing.

Description

Bush Orchard

The Bush Orchard is a semi-intensive or medium high density planting system of fruit growing with a plant density of 500-1500 trees ha^{-1} (as against 120 or 177 trees ha^{-1} in the traditional system) in which the tree resembles a bush. Either a dwarf cultivar or dwarfing rootstocks are used to control tree height. The modified central leader or any other suitable system of training is used. Light pruning in early years, consisting of thinning of branches around the trees after harvesting, and moderate pruning in late years, are carried out to restrict tree growth. Organic and inorganic fertilizer applications are used to ensure high fruit yield.

The advantage of Bush Orchard or the semi-intensive system of fruit growing is the lower cost of orchard establishment compared with ohdp and uhdp systems. This system is particularly important where land availability is not a limiting factor and for cultivars which are not suitable for intensive systems. For example, in the UK the main apple cultivar, Cox's Orange Pippin, proved rather difficult to handle under intensive systems. It should be noted, however, that bush or semi-intensive systems take a longer time (4-5 years) than intensive systems to give substantial returns; and pruning, hand thinning and harvesting operations are more intensive.

Tatura Trellis

The Tatura Trellis is a close-planting high density or intensive planting system, with rows of V-shaped trees running north-south. Each tree has only two limbs which grow east and west at an angle of ≈ 60° to the horizontal. This system of fruit growing was developed at the Irrigation Research Institute, Tatura, Australia in 1973. Results indicated that early and high yields were possible (Chalmers & van den Ende, 1975; van den Ende & Chalmers, 1982) and a number of orchardists established trial plantings of the Tatura system under commercial conditions. Cumulative yields in commercial planting of clingstone peach trees trained on the V-shaped Tatura Trellis system (average density 1800 trees ha^{-1}) were 145 t ha^{-1} after five growing seasons as compared with 52 t ha^{-1} in commercial low density orchards with conventional vase-shaped trees (average density 300 trees ha^{-1}). The system increases returns on investment and allows fruit farmers to respond more quickly to changes in the relative profitability of fruit crops and cultivars.

Pyramid Orchard

This is an intensive or high density planting system of fruit growing in which trees are planted at densities up to 3000 trees ha^{-1}. The trees are trained as a centre-leader pyramid having height and maximum spread measurements of 4 m. To avoid problems with spray penetration, shading of fruit-bud formation, poor fruit colour and difficulties with harvesting, fruit thinning etc., the trees should have a multi-canopy pattern with a very open texture.

On less fertile soils the pyramid system seems to prove beneficial (McKenzie, 1980). Already, very heavy yields of apples (130-170 t ha^{-1}) are being produced under this system in New Zealand. The system is also suitable for trees that require no support and summer pruning.

Cordon system

The Cordon system is used in France for peach culture using seedlings as rootstocks (Hugard. 1980). The most common planting distance is 4 x 1 m (2500 trees ha^{-1}). With peach it is not absolutely necessary to have a wire and stake device for maintaining the trees. Strong, regular and feathered trees during the first year in the orchard can be obtained by cutting down the yearling tree ≈ 10 cm above the bud union at the planting time during the first two years of the orchard life, it is important to remove the basal lateral shoots of the tree, which have a tendency to become too strong. and to leave the main vertical shoot, thus realizing the cordon shape.

Control of tree vigour is very important during the first two or three years. If the tree is too vigorous, fruit set is very low and the trees produce many water shoots; but when trees are too weak, they remain small and unproductive. In the cordon system, trees are 4-5 m high at the age of four years. Fruit production begins in the second year and full bearing is achieved in the fourth or fifth year.

Curtain system

This system of fruit growing is based on mechanization of harvesting and pruning, and was developed in Hungary by Gyuro et al. (1980) for apple growing. The mechanization of apple harvesting needs a tree with flexible yield-holding twigs and as few as possible rigid skeletons. The skeleton of the curtain is a central leader with one or two pairs of horizontal scaffolds. 180 cm and 220 cm long, in a tree density of 3000 ha^{-1}. The cropping twigs hang vertically to give a hanging twig-curtain which accommodates the horizontally vibrating fingers of the fruit harvester. Tree flexibility is very important because both the vibrating fingers and the fruit collecting devices penetrate into the tree canopy. The maximum height of the tree is usually 3.2 m.

The apple-Curtain system, using an over-row harvester, increases efficiency in apple growing without any loss in investment and yield. Cultivars with long, thin and prolific shoots perform best, The first Hungarian apple-Curtain plantings have about the same yield as hedgerow orchards of the same age and density but the size and colour of fruits are better because the curtain is thinner.

Hedgerow system

The Hegderow (fruit wall or tree wall) system is the most common modern system of fruit growing used for apple. pear and peach production. It is based on the use of growth regulators combined with root competition to reduce the size of trees, and is designed primarily for mechanized harvesting by an over-row harvester. In this system the trees are planted at a spacing of 30 or 50 cm apart in the row and 3 m between the rows with a tree density ranging from 2500 to 10 000 ha^{-1}. The trees are supported on wires and are trained as vertical cordons grown to a height of 2 m. Further growth is stopped by the application of 'Tree-hold', a commercial formulation of 1% naphthalene acetic acid in bitumen. The lateral growth of the trees into the alley-ways is controlled by mechanical pruning with a hedge trimmer combined with the use of SADH (succinic acid-2, 2-dimethyl hydrazine*). The effect of the growth retardant is to arrest the growth of the shoots which grow out following mechanical pruning and to induce fruit buds on shoots. In this way the growth of the trees can be contained and annual crops of high quality fruit obtained from the second year onwards.

The trees can be planted either in single, double or multi-row systems. The major advantage of the single row design is an improved light distribution within the canopy which is desirable for good fruit quality as well as for easy orchard management in the many alley-ways. A distinct drawback is that with very high tree numbers within the row, the light interception is far from maximal through the many alleys and hence the yield capacity of the orchard is reduced. Moreover, average fruit size may also be reduced when tree distances within the row become small. With multi-row systems both light interception and the production potential of the orchard increase, but light distribution and average fruit colour may become less optimal. With increase in the number of trees ha^{-1}, the sample space per tree derived from the sacrifice of alleys is reduced. Thus, one of the major advantages of the multi-row system is lost and average fruit size and colour may be reduced. Further disadvantages are the poor accessibility of the canopy for management and poor penetration of spray droplets compared with single rows. The latter disadvantage can lead to higher incidence of diseases in the middle sections of the multi-rows.

Meadow Orchard

The Meadow Orchard is a super-intensive or ultra-high-density planting system in which the fruit plants are grown at densities of 20 000-100 000 ha^{-1}.

The general concept of the Meadow Orchard has been described by Hudson (1971) and progress in solving some of the technical problems is recorded by Child (1972), Luckwill and Child (1973) and Luckwill (1978). This system is designed to produce fruit on two-year-old plants which are chemically disciplined and regulated to produce a simpler and smaller structured framework rather than the traditional well-branched trees. In the apple, plants are induced to form fruit buds in their first year by growth-regulator treatment. In the second year, plants flower and produce fruit, after which they are cut back to a stump from which a new shoot is regenerated to repeat the biennial cycle. Ultimately, harvesting is carried out by mowing the orchard (hence, the term 'meadow') with some form of combine harvester which would separate fruit from the shoots.

*Also known as Diaminozide. Alar and B-nine are trade names

The original Meadow Orchard system developed for apples is designed for mechanical harvesting, which provides an advantage on a large farm, but may not suit the small family farm because of the high cost of the machinery required. However, the advantages of an orchard of small trees that can be handled from the ground, has reasonable establishment and is very precocious in cropping, are quite attractive for the small grower who picks his fruits manually. Hence, Erez (1982), working with peaches, developed two feasible systems of Meadow Orchard, i.e. the mechanized system for a large farm and the intensive system for the small family farm.

The mechanized system

This system is developed for mechanized harvesting using a combine harvester that separates the fruit from a cut canopy. The idea is to detach the stem of the tree at harvest, leaving only a short stump from which regrowth would begin. The rest of the sequence of events is almost the same as described earlier. The mechanized Meadow Orchard (peach) has two main drawbacks: it is not suitable for cultivars ripening in mid- and late-season, due to insufficient time for top regeneration. The shock to the plant with complete removal of the green canopy is also very severe, accentuating latent problems such as a low level of certain elements, which lead to severe deficiencies. Continuous supply of these elements through the irrigation system can overcome this problem.

The intensive system

In this new Meadow Orchard system, the pruning is separated from harvesting by delaying it until after harvest. The tree is trained to two main shoots rather than one, as in the mechanized system (Fig. 2). One of the two shoots is headed back to a stump, allowing regeneration of new growth and flower bud formation in the course of the growing season.

The other shoot is not pruned; it fruits and is headed lightly after harvest to reduce shading on the adjacent growing shoot and is pruned to a short stump thereafter. Therefore, every shoot fruits every second year. In this system. annual fruiting could be obtained independent of time of harvest and the shock to the plant is reduced considerably by shifting the canopy topping.

Two main problems emerge with this system: one is how to obtain new vigorous annual growth from the shaded lower part of the tree; and the other is how to prevent shading of the lower part of the developing shoot by the remaining uncut shoot to allow development of flower buds along the entire new shoot. These problems can be overcome by manipulating the pruning. Yield of trees managed by the intensive system increases considerably in comparison with the mechanized system, due to increases in flower bud differentiation, fruit set, and yield per tree over the mechanized system. Enhanced fruit ripening is also achieved. Both systems have the advantages of precocious bearing, independence of tree support, and in the relatively simple and inexpensive means of orchard establishment from rooted cuttings. This makes commercialization of the two systems feasible. The Meadow Orchard system may not be beneficial for those fruit crops which are difficult to propagate by cuttings because of initial high cost of establishment as well as the problems of sprouting in rootstocks.

Application in tropical fruit production

Although a large number of tropical fruit species exist, only traditional fruits (citrus and banana) and plantation crops (cacao, coffee, coconut) are grown on commercial scales (Table 2). Most other tropical fruits, such as avocado, mango. papaya, guava, cashew, sapodilla, soursop etc., are grown as backyard trees. Moreover, production of traditional tree crops is declining. Thus, it appears that tropical tree crops, particularly non-traditional species, have remained neglected and unexploited despite their great potential.

In addition to the problems of post-harvest handling, processing and marketing, the following problems seem to have hindered the progress and development of non-traditional tree crops and have led to the decline in production of traditional tree crops:

(1) lack of modern and efficient systems of growing tropical tree crops;

(2) scarce and costly labour, particularly in the Caribbean countries;

(3) loss of competitive advantage of low cost of production. In fact. the Caribbean is perhaps the

region with the highest cost of production of tropical fruits.

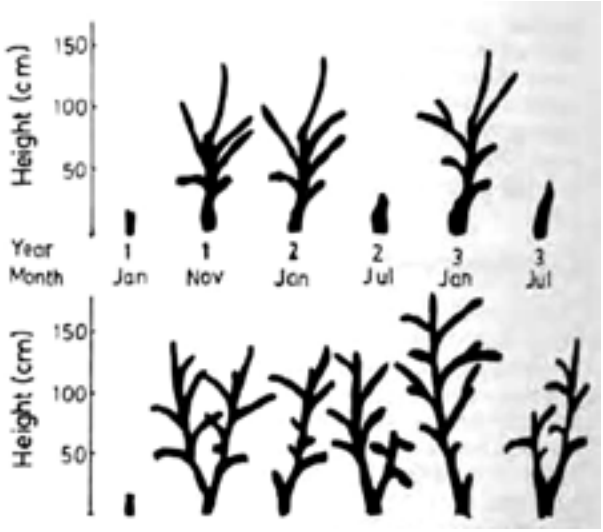

Fig. 2 A schematic comparison of tree development under the mechanized (upper) and the intensive (lower) system of Meadow Orchard (Erez, 1982)

There is clearly a need to introduce highly productive, intensive and mechanized systems of fruit production in tropical countries, especially in the Caribbean. Tropical fruit production could be greatly enhanced both in quantity and quality by using modern systems of fruit growing; failure to employ such systems may continue to contribute to the decline of traditional tree crops and under exploitation of non-traditional tree crops. Research is needed to study possible application of modern systems to tropical fruit species.

Unfortunately, little research is being carried out in different parts of the world to improve fruit growing systems, but research carried out in the past indicates that various modern systems of fruit growing can be employed beneficially for the production of tropical tree crops such as citrus, guava, cacao and coffee. For instance, Boswell (1977) reported that in citrus (' Naval' orange) denser planting increased total yield per acre. More recently. Hutton (1980) in Australia. and Trelistskaya (1981) in the Soviet Union tried semi-intensive and intensive systems of Fruit growing for citrus ('Valencia' and 'Hamlin' oranges) and obtained higher yields. Similarly, Chapman et al. (1979) induced

Table 2 Important traditional and non-traditional tropical tree crops grown in the tropics

Common name	Botanical name	Family
Traditional		
Cacao	*Theobroma cacao* L.	Sterculiaceae
Coffee	*Coffea* spp.	Rubiaceae
Coconut	*Cocos nucifera* L.	Palmae
Citrus		
Orange	*Citrus sinensis* (L.) Osbeck	Rutaceae
Grapefruit	*Citrus paradisi* Macf.	Rutaceae
Mandarin	*Citrus reticulata* Blanco	Rutaceae
Lime	*Citrus aurantifolia* (Christm.) Swing	Rutaceae
Lemon	*Citrus limon* (L.) Burm. f.	Rutaceae
Banana	*Musa* cultivars	Musaceae
Non-traditional		
Avocado	*Persea americana* Mill.	Lauraceae
Mango	*Mangifera indica* L.	Anacardiaceae
Papaya	*Carica papaya* L.	Caricaceae
Cashew	*Anacardium occidentale* L.	Anacardiaceae
Guava	*Psidium guajava* L.	Myrtaceae
Sapodilla	*Achras sapota* L.	Sapotaceae
Soursop	*Annona muricata* L.	Annonaceae
Custard apple	*Annona reticulata* L.	Annonaceae
Sweet-sop (Sugar apple)	*Annona squamosa* L.	Annonaceae
Bread-fruit	*Artocarpus altilis* (Park.) Fosberg	Moraceae
Ackee	*Blighia sapida* Koenig	Sapindaceae
Nutmeg	*Myristica fragrans* Houtt.	Myristicaceae
Carambola	*Averrhoa carambola* L.	Oxalidaceae
Mammee sapote	*Calocarpum sapota* (Jacq.) Merr.	Sapotaceae
Tamarind	*Tamarindus indica* L.	Leguminosae
W.I. cherry	*Malpighia glabra* L.	Malpighiaceae
Indian jujube	*Zizyphus mauritiana* Lam.	Rhamnaceae
Jackfruit	*Artocarpus heterophyllus* Lam.	Moraceae
Litchi	*Litchi chinensis* Sonn.	Sapindaceae
Mangosteen	*Garcinia mangostana* L.	Guttiferae
Pomerac	*Eugenia malaccensis* L.	Myrtaceae
Jambolan	*Eugenia cumini* (L.) Druce	Myrtaceae
Star apple	*Chrysophyllum cainito* L.	Sapotaceae
Durian	*Durio zibethinus* Murr.	Bombacaceae

early cropping of guava seedlings in a closely planted orchard (805 trees ha^{-1}) using a 25% urea defoliation spray. Singh et al. (1980) studied a medium high density planting system (Bush Orchard) of fruit growing for guava and obtained higher yields. Freeman (1975) advocated close planting of cocoa in early years and demonstrated a four-fold increase in yield. The trend for closer planting of coffee is already being exploited in many coffee-growing countries (Narasimhaswamy, 1968: Kabaara, 1969); very high density planting for coffee has proved successful in Puerto Rico (Vicente-Chandler et al., 1968; van Rest. 1968) and this is being investigated in Kenya (Huxley. 1970). These research findings suggest that there might be potential for application of some of the modern techniques of fruit production in tropical fruit species, but the application of such modern systems as the Hedgerow and Meadow Orchard must await more research and developmental work.

Recently, a research project has been initiated by the authors at the University of the West Indies, Trinidad. to develop a 'Meadow Orchard' system for guava production using the processing cultivar 'Centeno prolific' (Fig. 3). This research project involves the planting of rooted guava cuttings at three ultra-high densities (27 000, 37 000 and73 000 trees ha^{-1}) and studying the effects of several plant growth regulators (daminozide, ethephon, chlormequat, NAA, PP333, etc.) at different (250 - 3000 ppm) concentrations on growth, flowering and fruiting. Although it is too early to predict the feasibility of using the Meadow Orchard system on a commercial scale for guava production , preliminary results are quite encouraging. Not only was fruiting obtained in the first year of planting but estimated yield, as high as 27 t ha^{-1},was recorded in one of the treatments which far exceeds the yield (10.8 t ha^{-1}) obtained four years after planting under traditional systems (Singh et al., 1980). This encouraging performance of guava under the Meadow Orchard system suggests that commercial application may become a reality in the near future.The new orchard systems such as the Hedgerow, Cordon and Curtain appear to be equally attractive and promising for guava production , but require intensive research for their development. At present, the application of the Meadow Orchard and other high density planting orchard systems for production of mango, avocado, cashew, sapodilla, etc. seems not to be easy because of the difficulty of vegetative propagation by cuttings in these fruit crops. Research has also been initiated to remove this and other constraints to the application of modern fruit growing systems in as many tropical fruit crops as possible. It may be appropriate to mention that the main stimulus to the development of intensive and semi-intensive systems of apple production in temperate climates was the development of dwarfing and semi-dwarfing rootstocks. The absence of such rootstocks for tropical fruits has undoubtedly been a major inhibiting factor in the past. Now that chemical dwarfing and the production of dwarf mutants by irradiation are possible, a new field of research is opened up which may help develop modern systems of fruit growing in tropical fruit species.

Fig. 3 A partial view of the field trial of 'Meadow Orchard' being developed by the authors for guava cv. 'Centeno Prolific' (Processing cultivar). Plot 6 in the photograph shows a plant density of 37 000 plants ha--1 (90 x 30 cm spacing)

Conclusions

The development of modern systems of fruit growing marks an important breakthrough in the field of fruit production. These modern systems have almost revolutionized fruit production by providing precocity and increased productivity coupled with a reduction in production cost and labour demand. The choice and success of various systems (Pyramid, Cordon. Hedgerow, Meadow Orchard, etc.) will depend on economical, technical. climatic as well as soil conditions and on the behaviour of the fruit species and cultivars. Increasingly, some of the modern systems of fruit growing are being used on commercial scales in Europe and USA for temperate fruit production. Unfortunately, modern systems of fruit growing, particularly high density and ultra-high density planting systems (the Hedgerow, Meadow Orchard),

still remain unexploited in the field of tropical fruit production, despite their apparent potential. Attempts are now being made to study the application of these systems for improvement of tropical fruit production. In Trinidad, research results indicate that the Meadow Orchard system appears quite promising for guava fruit production. However, further research is needed before the system can become fully applicable on a commercial scale.

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