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APPLES LIGHT AND ORCHARD DESIGN FOR ENHANCEMENT OF YIELD AND FRUIT QUALITY

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Abstract

There has been large scale proliferation of different production systems for apples over the last forty years. All of these systems have to work within the constraints of the physical, biological and economic environment modern fruit growers find themselves in. Within the biological constraints, the importance of light interception in determining yield and the deleterious effect of shading on yield and fruit quality has been clearly demonstrated over the last thirty years. The fruit grower does, however, have a range of tools at his disposal to improve fruit productivity size controlling clonal rootstocks, tree training and pruning, and genetic variation. The canopy of the cultivated apple has shown itself to be extremely adaptable and amenable to physical manipulation. Within the many modern systems propounded there are several common themes a rapid achievement of high light interception and early cropping, the maintenance of good light penetration into the canopy at all times and efficient fruit harvesting.

Introduction

There has been a proliferation of new production systems for apples throughout the world in the last forty years. With the ease of international travel and dissemination of information, there has also been considerable cross fertilisation of ideas between different geographical areas. All systems for growing fruit have, however, to work within clear physical, biological and economic constraints coupled with a set of horticultural tools and skills. In this review I will endeavour to examine the tools the pomologist has at his disposal, the constraints to production and some of the solutions that are widely used.

It is also important to point out some of the general trends that have been impinging on apple growing over the last few years and influencing the development of new systems of growing. World production has been rising rapidly which means that growers are facing strong international competition with attendant pressure on prices, particularly for established cultivars. The green movement is here to stay, so there has been and will continue to be pressure to reduce the input of chemicals to fruit production. Although twenty years ago there was great interest in the future role of plant growth regulators in apple production, this declined in the mid 1980s when a plant growth regulator, Alar, was effectively banned following a blaze of bad publicity.

Tools

Horticulturists are skilled manipulators of the plant kingdom. Within pomology, we have, for example, clonal rootstocks, genetic variation and tree training and pruning skills, all of which enable us to manipulate the apple tree to produce a higher yield of top quality fruit.

It is important to take a little time to explain the growth characteristics of the apple tree for a meeting of avocado specialists. Apples are a deciduous, fruit tree widely grown in cool and warm temperate regions of the world. They have a winter dormancy, which is broken by chilling, and normally show one annual flush of growth lasting 2-3 months. Flowers are initiated in mid to late summer in terminal buds of current season's shoots, on axillary buds in the axils of the leaves on this growth or on older wood, on short spurs, which can remain floral for many years. Fruit size is often smaller from flowers in lateral positions and from older spurs. Cultivars differ considerably in their ability to form flower buds in axillary positions on current year's wood. The number of flowers and subsequent number of fruitlets on the tree in spring are often far more than are needed for a commercial crop so are usually reduced by chemical and/or hand thinning.

Apple growers are fortunate in having a whole range of clonal rootstocks available to them, rather than relying on own-rooted trees or seedling rootstocks. Clonal rootstocks give the advantages over seedling stocks of predictable tree size control, uniformity of tree size, improvements to fruit quality and resistance to soil borne pests and diseases. For tree size control, rootstocks are available to give a tree at maturity from 1 m to 6 m high. In general, the more dwarfing the rootstock the more precocious ie. the earlier it comes into cropping. There is not only a wide range of rootstocks available, but in some cases e.g. with the dwarfing stock M.9, a range of clones within one type have been selected by nurserymen. There is also a considerable breeding programme worldwide which is continuously adding new rootstocks to the arsenal.

Within the many thousands of apple cultivars, there is considerable variation in tree habit as well as the obvious differences in fruit characteristics. Spur types, which show short internodes and compact habit, have been widely used in the United States. The ultimate spur type is the Wijick mutation of McIntosh which produces a single stem, with very short internodes and a spur in each axillary position. Red sports of commercial cultivars are often selected to improve the appearance of a striped red apple.

Tree pruning and training has been practised for centuries and apples can easily be trained into a whole range of shapes. Gardening books of yesteryear often carried descriptions of many of these ornate forms. It is important to emphasise that the apple grower not only prunes his tree to remove unwanted growth and to direct growth, he also makes considerable use of tree training branches or shoots are tied into particular positions, bent down and tied up or clipped to wires or posts. This manipulation can begin before the tree reaches the orchard when it is in the nursery. With the current emphasis on precocity, this has resulted in physical and chemical techniques to improve the feathering or branching of the tree in the nursery. This has meant that some growers are now able to fruit their trees in the first year in the orchard. It also means that the initial branch framework for the future tree is already present in the tree from the nursery, making early tree management much easier.

Constraints

Production constraints can be physical, biological, economic and environmental. With all perennial fruit crops there is a continual need to maintain physical access for spraying, picking, pruning and other cultural operations. Despite the attraction of the meadow orchard concept (Hudson, 1971), it has not proved to be successful for apples because, among other limitations, it relied heavily on plant growth regulators.

Plant productivity depends upon the absorption of light energy by the green tissues and the conversion of that energy into biomass *via* photosynthesis. A number of studies have shown a linear relationship between light interception and dry matter production of several crops, including apples (Monteith, 1977). Dry matter production, however, is the biological yield, and orchardists are interested not so much in the biological yield but the yield of fruit. Fruit yield has also been shown to be linearly related to light interception (Palmer, 1989; Wagenmakers, 1991; Lakso, 1994), although due to the deleterious effect of shade, this latter relationship would be expected to be curvilinear as light interception approaches 100%. Nevertheless, high light interception is essential as the prerequisite for high yields.

Although high light interception is needed for high yields per unit land area, shade can have a deleterious effect on fruit quality, fruit set and flower initiation. Table 1 gives a summary of these effects. Shading can arise from within or between tree sources, including windbreaks. Fruit size, red skin colour, soluble solids concentration are all reduced by shading (Jackson, 1970; Barritt *et al.* 1987). This seems to be a general phenomenon among perennial tree fruits and has been reported for apples, citrus, red raspberry, kiwifruit, cherries, peaches and grapes (Palmer, 1989). Shading can also result in a reduction of flower initiation and fruit set. These effects of shade could be mediated *via* a direct effect of light on carbohydrate supply or through effects on the red/far red ratio. Unfortunately the two factors are highly correlated within plant canopies. Although there have been attempts to separate the two effects with grapes the results have not been very conclusive (Kliewer & Smart, 1989). In some environments excessive amounts of light falling on the fruit can result in downgrading of the fruit due to sunburn. For high yield and, in particular, high fruit quality, the orchard needs to combine both high light interception and good light distribution within the tree (Wünsche *et al.* 1996).

There is, I suppose, no end to the possible ways of arranging apple canopies in space. The bottom line, however, in all ways of growing fruit is whether the system is economic. Yield and fruit quality determine the income but the cost of establishment and maintenance determine the expenditure. If expenditure exceeds income then, however elegant the system, it is not economic.

The last major constraint is the orchard environment the soil, the climate and the grower. The soil can impose serious limitations to rootstock choice and similarly the climate can seriously limit the choice of rootstock and cultivar. The grower himself is not always seen as a constraint but it is important that the grower has the technical expertise and skill to manage the system; he may not, for example, be able to successfully change from a system he knows well to a new system.

Table 1 Generalised effects of shade on apple fruit quality, storage disorders, flowering and fruit set

Decrease	fruit weight
	Fruit red colour
	soluble solids (Brix)
	bitter pit
	flower bud numbers
	fruit set
Increase	shrivel
	fruit firmness

These therefore are the main constraints upon fruit growing. The successful grower, however, makes full use of the tools he has at his disposal to exploit the positive advantages of his crop and environment and to minimise the disadvantages.

Solutions

<u>Common threads</u>

The interrelationships between the choices open to the grower have been likened to "an orchard system puzzle" (Barritt, 1992). This is a helpful illustration as it emphasises the linked nature of the management choices rootstock, tree quality, tree arrangement, support system, tree density, tree training and pruning.

Although there have been many new training systems for apples described over the last forty years, each with their enthusiastic adherents, there are a number of common trends within these systems 1) a rapid achievement of high light interception and early cropping 2) efficient harvesting and 3) the maintenance of good light penetration into the canopy at all times.

Early cropping per hectare and the rapid establishment of the canopy has been achieved by high tree densities (1500-5000 trees/ha), planting well feathered trees and an emphasis on tree training rather than pruning. In order to avoid later problems of excessive vegetative vigour resulting in poor fruit quality, size controlling rootstocks have been widely used, with more emphasis on rootstock inducing smaller tree size with higher tree densities. The push for improved precocity has come from two economic directions; when orchards are replaced, the orchardist would like to see a positive cash flow from his orchard as soon as possible, particularly if he has had to invest heavily in his new orchard, and secondly, new cultivars often attract high prices in the market and the sooner a grower can exploit this situation the better.

Traditionally, in many parts of the world apple fruit have been picked from ladders from large trees. In many new systems there has been a strong emphasis on reducing the size of the tree so that more, if not all, of the fruit can be picked from the ground. If tree size is reduced this also means that the canopy is easier to spray, prune and thin. There have also been some attempts to mechanically harvest dessert apple fruit and this has led to drastic changes in the canopy form to accommodate the harvester. Although this would further reduce the cost of picking, there are at present no commercial orchards using mechanical picking. There are, however, a number of mechanical systems to enhance the hand picking of fruit for use on current systems of production.

As shade is known to be deleterious to fruit quality, all systems ensure that sunlight can penetrate into the canopy. This frequently relies on renewal pruning to replace branches that have become too large for that position in the tree. To allow penetration of light into the canopy, many modern orchard systems maintain a conical shape to the tree or develop a thin canopy layer.

Alternative solutions

As has been alluded to already, there are a large number of canopy forms and some of these are illustrated in Figure 1.

Conical trees

The Dutch have spearheaded the use of intensive systems, with tree densities of 2,000-3,300 trees/ha, based on a small conical shaped tree, the slender spindle (Figure 1). Trees are frequently grafted on the dwarfing rootstock M.9, and tree height is 2-2.2 m. All tree management operations pruning, thinning and picking can be done from the ground or with short step ladders. The high tree densities ensure a high light interception and the combination of a size controlling rootstock with the conical shape ensures that light can penetrate into the lower parts of the canopy. Although use has been made of even higher tree densities and multi-row rather than single row systems, low fruit prices have made some of these very high density systems economically questionable. The French axe system has a similar conical tree shape, but is planted at lower tree densities than the Dutch spindle bush and is permitted to grow to 3-4 m tall (Figure 1).

Planar canopies

To improve light penetration into the tree, the canopy can be trained into a thin layer which, with a suitable wire trellis, can be inclined at different angles to the vertical. The Australian Tatura Trellis, originally designed for the mechanical harvesting of peaches, has been used for apples. There have, however, been numerous other forms of V and Y canopies (Figure 1). In some cases individual trees are trained into two halves, in other cases alternate trees down the row are trained to the right and to the left. The horizontal Lincoln canopy was also designed for mechanical picking but suffered from excessive annual, vertical shoot growth from the horizontal canopy, with attendant shading of the fruit below. Although such growth could be mechanically pruned off in the summer time, fruit colour was often poor with red skinned cultivars. A narrow depth of canopy does not necessarily ensure good light penetration.

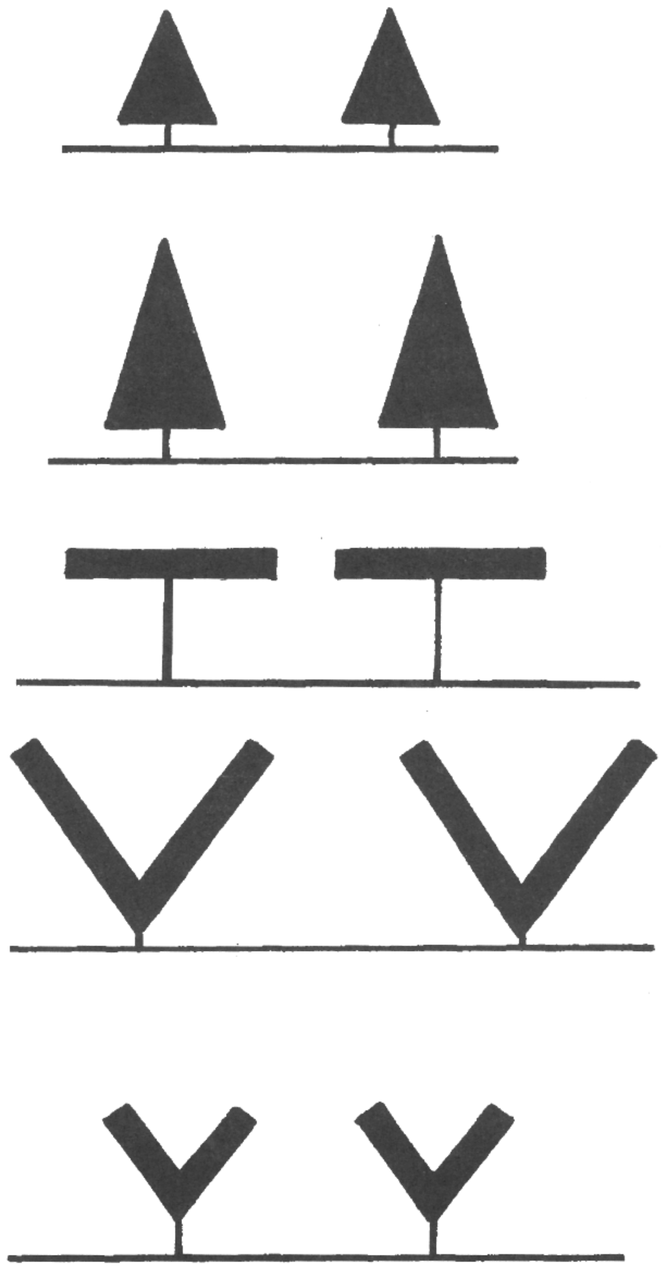

Figure 1 Cross sectional outlines of five apple production systems, reading from the top of the page - slender spindle, French axe, Lincoln canopy, Tatura trellis and Y trellis. Tree outlines are approximately to scale

Concluding remarks

The apple canopy has proved to be extremely adaptable to manipulation and this coupled with the extensive range of size controlling rootstocks has ensured there is no shortage of innovative canopy designs. "The discussions and controversies between orchard management specialists and between growers about planting distances and tree training systems for a given fruit species undoubtedly began with the first orchard; they will last as long as fruit trees are planted" (Hugard, 1980).

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