The prospects for improved productivity of stone and pome fruit crops from improved plant management

D.J. Chalmers

Irrigation Research Institute, Tatura, Victoria. 3616.

Summary

A number of conditions and influences in the past, present and future, have or will bring increasing pressure to bear on the systems presently used in Australia for growing stone and pome fruits commercially. These factors, acting from without and within Australia, will, sooner or later generate changes in our methods of production that will be aimed at radically increasing productivity. Few such changes have so far occurred in Australia, whereas many of the countries with whose fruit ours must compete on world markets, are well on the way to revamping their fruit growing industries.

The prospects for improved productivity of stone and pome fruits include many tested technologies developed in the recent and even the not so recent past, that have won only scant consideration in present orchard systems; in addition to many important prospects that await further research and development. By far the most important of the neglected technologies is high density planting, a host of systems of which have been developed that could radically increase our present productivity.

For some reason(s), however, they have largely been ignored. Considering how widely such systems have been used elsewhere an objective study of the reasons why our industry has not adopted them may reveal important areas for research, development and/or advisory activity.

Introduction

The aim of farming, for most farmers, is to make money. For them, to improve productivity means to reduce the unit cost of production. This can be tackled by reducing the inputs (costs) without a proportional decrease in returns from production or alternatively one can increase production with less than a proportional increase in costs.

Both the "cost cutting" and "yield increasing" approaches to improving productivity will be needed to ensure commercial fruit growing can be economic in the future. Paradoxically however, the approach to one is often inimical to the other and horticultural scientists and advisors need to have a clear knowledge of which stands the best chance of succeeding and therefore which to emphasize in their respective approaches to increasing productivity. This paper considers which of these approaches are most likely to be appropriate for the circumstances with which the stone and pome fruit industry must contend and consequently what technology is available or will be needed to allow the industry to remain competitive overseas and viable in Australia.

The Pressures for Change from Existing Production Systems

To gain some insight into the changes which may occur, one needs to consider the pressures, past, present and future that may be expected to generate change.

Growing of temperate fruit crops has been affected more adversely than most agricultural industries by market changes caused by Britain's entry into the European Economic Community. While this has caused some economies in orchard operations such as reduced and mechanical pruning, in general the effect has been to retard progress towards increased productivity, especially where high capital inputs were needed.

Lack of confidence in the future and lack of financial resources to commit to changes has entrenched many outdated management systems and practices. Since measures taken by the Government to rationalize and stabilize the fruit growing industry and by the industry itself to diversify its export markets have begun to improve prospects. the industry will need to change methods of production to make up the leeway in productivity lost to other fruit exporting countries during the recession in the Australian fruit industry.

In spite of these improved prospects the future of fruit growing will remain uncertain for the time being. Orchardists who replace or extend their plantings should therefore be looking for systems that provide quick returns to allow flexibility in cropping and rapid changes from unprofitable crops to profitable ones.

Higher interest rates and competition for finance from enterprises that have faster cash flows will also make early yields an important attribute for new orchard investments.

The availability of new varieties of stone and pome fruit should increase as a result of importing and breeding, stimulated in part by impending legislation for plant patents. Furthermore, more sophisticated (and successful) advertising campaigns may stimulate interest in new and different cultivars of the traditional stone and pome fruits. Orchardists who want to obtain the more lucrative markets that develop with and shortly after the release of new cultivars and fruits will be better served by early yielding systems.

The cost in energy, raw materials and labour of applying fertilizer, spray and of carrying out other management practices such as harvesting will accentuate the need for high yields.

Harvest labour is the greatest single cost in fruit growing, being around 20% of the annual operating cost. Existing mechanical harvesters, such as they are, have been designed to fit standard (wide spaced) orchards. The direction of future developments in orcharding will depend to a considerable extent, on how successful such machines become in the next decade. If a highly successful harvester was developed for standard orchards it could retard, if not prevent altogether, any change to more productive orchard design.

Most of these factors point to increasing yield as the most important approach to increasing orchard productivity. In particular orchardists who obtain high yields early in the life of their plantings are more likely to have the flexibility needed to avoid the worst of the downturns and take most advantage of the upturns of the fruit industry.

The Potential for Technological Advance

Improved land use and earlier yields generated by high tree density have long been recognized as the agronomic keys to increased orchard productivity. In some countries the principle of close planting has already been widely adopted by industry. As long ago as 1968-69 almost all apple trees planted in Holland were on Malling IX rootstock (Table 1). This is a dwarfing rootstock and, depending on scion variety, is only suitable for orchards with a tree density of 1000 - 2000 trees per ha or greater. As a result of this change, yield per ha increased by 50% while production per man hour in Holland more than doubled between 1955 and 1967 (Roosje 1970).

TABLE 1. Rootstocks used for propagation of apple trees in Holland (Roosje 1970).

Year	Number of Trees (000's)	% of each rootstock					
		IX	II	IV	VII	Seedl.	Other
1951/52	959	15	12	21	17	16	19
1965/66	2170	56	15	12	9	0.3	8
1968/69	2018	82	7	3	3	0.1	5

There is considerable scope for increasing productivity in Australia by increasing tree density. Only a small proportion of existing fruit tree plantings have more than the standard number of trees per ha (250).

In the Goulburn Valley in Victoria which produces almost half of that State's deciduous fruit crop, only 4% of the existing orchard area is planted with more than double the standard tree density (Keatley pers. comm.). Similarly only a small proportion of existing orchards in NSW are densely planted although there appears to be some progress towards higher tree densities for apples. The average tree density in NSW is 272 trees per bearing ha, but increases to 406 per non-bearing ha. The equivalent data for pears, however are 243 and 261 trees ha-1 respectively (R. Sweedman pers. comm.). This difference between fruit species is undoubtedly due to the wide range of rootstocks available to control the size of apple trees in dense plantings.

While high yields can be obtained (with difficulty) from standard orchards given good soil and well managed irrigation, there is no alternative to high tree density for early yields per ha. Consequently high tree density must figure prominently in orchard design and management in the future. Many of the important areas for technological advance in orcharding will be related to, or required for, implementation of closer planting systems.

Important Areas for Technological Advance

In most areas there are opportunities to improve productivity by using existing but poorly utilized technologies and newly developed technologies, as well as there being prospects for further developments from research.

a) Planting material for New Orchards

The present system whereby orchardists obtain their trees from nurserymen limits the use and the usefulness of high tree densities. The most serious limitation is the cost, which is very important to orchardists and strongly discourages their interest, but is misunderstood. Trees cost $3 each or more from nurserymen at present, making the cost of trees for a reasonably intense orchard around $3000 ha-1. The return on capital expended on trees, however, is usually better for intense than standard orchards and there is a strong need to develop understanding of that fact, and what it means, among orchardists.

Nursery-grown trees can not be reliably obtained in sufficient numbers, however, for high-density plantings, without providing the nurseryman with an order in advance. It can take 2 years from the time of placing the order until delivery and a further two years after planting until the earliest possible crop. This adds up to a lead time of approximately 4 years between deciding to produce a fruit variety (or species) and producing the first crop, by which time many of the reasons for making the decision may have changed. Nurserymen propagate fruit trees by budding or grafting the scion variety onto a rootstock. Some orchardists grow their own trees by these methods but considerable skill is required and nursery operations frequently conflict (in time) with those of the orchard.

Many species of deciduous fruit trees, however, can now be propagated by cuttings (Issell et al 1976, 1979) which although still requiring skill fits in better with other orchard operations. This method also has the advantage that it is the fastest possible way to propagate a fruit tree. For example peach trees in a high density orchard at Tatura Irrigation Research Institute produced a crop of 25 tonnes per ha only 18 months after the trees had been propagated from cuttings.

Although these methods of propagation are suitable for and are being used by some nurserymen, their main advantage is that they can make the orchardist self-sufficient for planting material.

Furthermore the cost of trees can be reduced by up to 90% if the orchardist grows his own trees. These factors make strong arguments for encouraging fruitgrowers to consider tree propagation as part of their overall management task.

Research is still needed to develop simple methods for propagating those species that so far can not be propagated from cuttings. On the other hand, newly bred and imported cultivars will not be available in sufficient quantities to propagate by these means. More highly specialized techniques such as meristem culture will be required by nurserymen to rapidly multiply new clones or cultivars.

b) Plant Population

In the past the orchardist has aimed to allocate an amount of space to each tree which it fills but does not overgrow once it has reached its maximum size. To allow an appropriate amount of space in a planting for fully grown trees for most fruit species and soils meant 250 - 300 trees per ha. Even with good management such planting densities led to delays of between 4 and 8 years before a significant crop could be expected and between 9-20 years before the planting reached its maximum yield. Dwarfing rootstocks have reduced the maximum size of the tree and the time taken to reach that size, and consequently dwarfing rootstocks when available can be used with increased tree density to bring about much earlier bearing.

Nevertheless there is a period during which growth is entirely vegetative and fruiting is not possible. There is also a period even for dwarf trees, after the trees have begun cropping but have not yet filled their space. when full production is not possible. Furthermore during this latter period the objectives of ones management conflict. Since vegetative growth and fruit growth compete for the available assimilate (Proebsting 1958, Chalmers and van den Ende 1975), neither rapid tree growth nor full fruit production is possible.

The ideal system for timeliness would use a sufficiently vigorous tree or sufficiently high tree density to fill the allotted space during the mandatory phase of vegetative growth (1 year for peaches, plums and apricots. 2 years for apples and pears), and then stop vegetative growth and initiate full cropping in the next season.

The former can be readily achieved using more vigorous rootstocks and in most instances self-rooted cuttings as described above. The latter will require the skilled manipulation of the plant from the start of the cropping stage, but a number of management strategies are capable of suppressing vegetative growth. Cropping, summer and winter pruning (Proebsting 1958) and inhibiting root growth (Chalmers and van den Ende 1975) suppress vegetative growth. Management strategies being evaluated at Tatura that integrate all these measures have proved successful in containing the growth of self-rooted peach trees, while simultaneously increasing yields over the non-regulated systems.

The productivity of self-rooted trees grown for 4 years by these methods have been compared with trees budded onto a dwarfing rootstock (Prunus tomentosa). Table 2 compares the estimated productivity and the cash returns of the respective orchard systems. No allowance is made for the cost of the trees in this table which would also favour the own-rooted trees, perhaps substantially.

TABLE 2. Estimated yields[A], production costs and returns of close planted orchards of peach trees grown from own-rooted cuttings or from trees budded into dwarfing rootstocks.

	Golden Queen budded onto *Prunus tomentosa* seedling rootstock		Golden Queen propagated from cuttings	
		Cumulative[B] crop value ($)		Cumulative[B] crop value ($)
Tree density (trees ha-1)	4166	-	4166	-
Time needed for propagation (years)	2		0.25	
Time from planting to 1st crop (years)	2.5		1.25	
Crop second growing season (tonnes ha-1)	-	-	25	4500
Crop third growing season (tonnes ha-1)	29	5220	55	14400
Crop fourth growing season (tonnes ha-1)	40	13140	70	27900

[A] Estimates based on tree size and/or individual tree yield records.
[B] Based on $180 tonne-1 being price paid by processors for Golden Queen peaches in 1979.

Although the productivity of the orchard budded onto Prunus tomentosa seedlings is high it has been left well behind by the "controlled" self-rooted trees. Furthermore at this stage the budded trees still require several years to reach full size and yield while the self-rooted trees have filled their space and will reach their ceiling yield with this season's harvest.

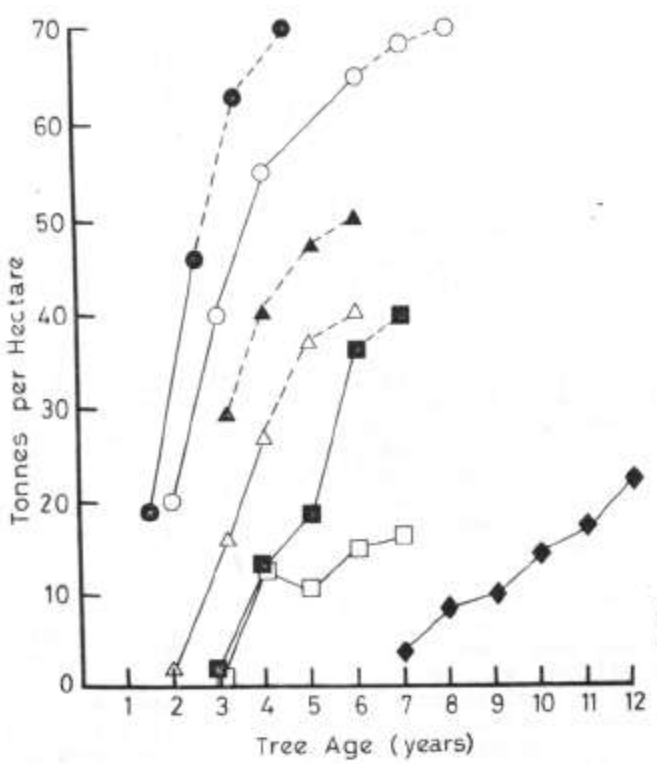

Fig. 1. Yield per ha of Golden Queen peach trees grown in various systems and plant densities. Regulated bed planting, 4166 trees ha-1 (●); Tatura Trellis, 1668 trees ha-1 (○); Bed planting on dwarfing

rootstock, 4166 trees ha-1 (▲); Palmette, 1157 trees ha-1 (r); Standard planting, modern management 335 trees ha-1 (■); Central leader hedgerow, 346 trees ha-1 (q); Standard planting, older management, 272 trees ha-1 (u).

Figure 1 compares the likely yields of peach trees in a number of systems and a number of densities presently being evaluated at the Irrigation Research Institute. In the Goulburn Valley one might expect the yield from well grown and managed trees in a standard orchard to reach 40 tonnes ha-I after 7-9 years. At higher tree densities however yields of 75 tonnes ha-1 are possible. The time taken to reach that level depends upon the initial tree density and the time taken for the trees to fill their space. Overall, after taking into account earlier yields, higher tree density should result in at least a doubling of productivity over the life of the orchard.

The effect of denser tree populations on productivity will also be affected by future change towards shorter economic life for the orchard such as could occur with the introduction of improved cultivars etc. If the life of the orchards represented in Fig. 1 was to reduce to say 10 years it is obvious that the advantage of the very dense plantings would increase further.

c) Effect of Geometry on Productivity

Geometry is mostly used as a management aid to i) facilitate tractor movement between closer rows, ii) assist in the control of vegetative growth at high plant density, iii) increase yields and productivity, iv) position fruit for mechanical harvesting.

1) Improved Land use

While initial yield is related to the number of trees ha-1 final yield is related to amount of effective canopy surface area. Since no deciduous tree crops on growth made during the current season, only the scaffold frame present in the winter before cropping can be considered when estimating the cropping surface area. That is shoots that grow into gaps in the canopy during the growing season can not bear fruit in that year and may shade productive limbs lower in the canopy.

Tree geometry can be manipulated (by pruning and training) to fill the allotted space with fruiting spurs and laterals to optimize land use and indeed it is virtually impossible to obtain 100% land use without such methods. Allowed to grow naturally. fruit trees will adopt a hemispherical or bullet shape which if formed into a row can utilize a maximum of 60% of land area after allowing for tractor access. To increase this proportion tree geometry must be manipulated to allow tractors to pass beneath the limbs.

2) The Effect of Geometry on Light Interception and Photosynthesis

Orchard canopies vary a great deal in the efficiency with which the light that is intercepted is utilized. Jones (1972) has shown that the light does not penetrate deeply into the tree canopy and only the leaves within km of the canopy surface are well illuminated. Source sink relationships influence photosynthetic activity of fruit trees strongly (Chalmers et al 1975). To maintain high overall rates of photosynthesis, fruit need to be located near leaves receiving satisfactory levels of light. Trees should therefore be structured in the orchard in such a way to allow light to be intercepted more evenly over the maximum area of canopy surface through which fruit can be evenly distributed.

While it is simple enough to achieve uniform light distribution over a maximum surface area it is more difficult to maintain uniform fruit distribution. We have found that fruit distribution is affected by non-environmental, probably hormonal, factors in the bearing limb with the physiological environment being much more favourable for fruit set and growth at the ends of limbs (Dann and Chalmers unpublished data). If the hormone factors controlling fruit growth and distribution can be determined and brought under control substantial increases in productivity and manageability will be achieved in the orchard.

3) Role of Tree Geometry in Improved Tree and Orchard Management

Mechanical pruning is used to a considerable extent in orchards in Australia to reduce the cost of hand or secateur pruning. For most orchards this means trimming the uppermost surface of standard (vase-trained) orchard trees, which results in proliferation of annual shoots on the top surface of the canopy with the fruit located at varying depths beneath. With each successive machine pruning the layer thickens and intercepts more light. Since the developing layer is composed of current-seasons growth it contains no fruit and hence the efficiency of the tree for fruit production is reduced.

This problem would be overcome if the tree was trained to allow the pass of the pruner to be aligned with the bearing canopy surface. Planar (but not horizontal) canopy surfaces such as can be developed with hedgerows and in Tatura Trellis type plantings would satisfy this criterion.

While attempts to mechanically prune standard trees have been modestly successful, mechanical harvesting of standard trees for most fruit species is still only a dream. The main problems are that fruit are fragile and that the only economically feasible system for recovering fruit that have been mechanically removed from the tree is gravity. This combination results in a high proportion of fruit striking branches and other fruit and being damaged. Standard trees are also large and require a large and complicated machine to envelope them for harvest.

Obstructing lower limbs in hedgerows altogether prevent positioning of a catching frame in that system and since every fruit harvested must fall through the tree most fruit would strike a limb on the way down should it be made possible to position the catching surface beneath hedgerow trees. These difficulties led to the conclusion that it may be simpler to structure the orchard for machine harvest rather than build a machine to fit existing trees (Dunn 1978; Chalmers 1978). The properties of trees required for shake-catch harvesting of fruit have been defined (Claypool et al 1969; van Heek and Gould 1977). The criteria must allow a catching frame to be positioned beneath the tree(s) and ensure that the fruit falls out of the tree canopy without striking branches, spurs or laterals.

An important advantage of designing trees to fit the harvester is that it can simplify the design and hence reduce the cost of the harvester. For example effective harvesters have been built for the Lincoln canopy in New Zealand and Tatura Trellis for a or less of the cost of commercial machines for standard plantings.

Studies of mechanical harvesting at Tatura indicate one other aspect of orchard geometry that is important in facilitating mechanical harvesting. Fruit have too much inertia to allow selective or gradual harvesting by using different shaking forces. A force that is sufficient to shake a tree will dislodge the fruit indiscriminately. This generates two problems, first, fruit can not be selectively harvested according to stage of ripeness and secondly a large proportion of the fruit fall simultaneously onto the catcher surface when the tree is first shaken.

The former of these problems results in substantial fruit losses since fruit on a tree varies substantially in maturity and for some species of fruit (eg peaches) this includes some categories of maturity that are commercially unacceptable. The latter problem causes a large number of fruit-upon-fruit collisions on the catching surface and collecting areas of machines which causes bruising. Smaller trees or single limbs can be shaken with less force to enable selective harvesting (van Heek pers comm). Small trees would also yield fewer fruit per tree which would simplify catching the fruit and reduce the number of fruit-upon-fruit collisions.

These advantages of smaller trees were supported by a study of mechanical harvesting of the Tatura Trellis. In that work Chalmers et al (1978) found that riper fruit towards the ends of the limb could be selectively harvested with lighter shaking and that fruit-upon-fruit collisions could be largely avoided. The latter result was due partly to machine design and partly to the fact that each Tatura Trellis tree carried only 300 - 400 fruit compared with 1000 - 1500 on an orthodox tree.

Regulation of Plant Growth and Development

One advantage (and there are few) of the perennial frame of a fruit tree is that it does not have to be grown each year. Hence. one needs only sufficient annual growth upon which to develop fruit buds for the future, and for some species that develop fruiting spurs, only leaves are needed. The corollary of this point is that it is wasteful of potential to expend assimilate resources growing tree and shoots if it can be avoided or controlled. It has been established (Proebsting 1958, Chalmers and van den Ende 1975) that dry weight gain by fruit and vegetative growth on fruit trees is interconvertible and that the tree's strategy of assimilate distribution can be manipulated by hormones and by alteration of the trees environment (Luckwill 1970).

a) Use of Hormones

So far research has delivered little of the agronomic promise for regulating plant growth and productivity using natural hormones and synthetic growth regulators. The few agronomic applications are presently confined to herbicides where the hormone is used as a phytotoxic agent or where it is plainly a short duration trigger or delaying agent for an incipient natural process (for example the use of ethylene and ethylene suppressors to control fruit thinning, ripening and preharvest drop).

We have not yet succeeded, however. in being able to manipulate plant processes such as assimilate distribution or fruit growth or photosynthesis for long enough to alter productivity. Yet we know much about the details of the role of plant hormones in such processes. We perhaps need to take a lead from our successes. In most instances the successful hormone treatment has set in

train events which were otherwise programmed to occur. Our research should be more strongly directed towards developing an understanding of the relation between endogenous hormone changes and physiological events within the whole plant. We should be studying the gradients and changes of hormones that occur in organs as they develop in order that we can relate growth and productivity to endogenous hormone levels and relationships. We need that understanding before we can hope to gain the ability to manipulate the plant from within; to control the quantity and quality of the hormone messages generated within the plant to regulate growth, development and productivity.

It is in this context that I think the view that it has all been done (from the point of view of agricultural research), is falsest. This area of research must be energetically and innovatively studied.

b) Manipulation of Management Practices

There is considerable scope in horticulture for adjusting our existing management practices to increase the harvest index. Adjustments need to be based on the principle that there are distinct periods during the fruit growing season when vegetative growth is the stronger competitor for assimilate; and periods when fruit growth almost completely suppresses vegetative growth. That is, there are periods when the fruit needs assistance and periods when the fruit is clearly the stronger competitor and will use all of the resources made available by the leaves, regardless of how favourable conditions are for vegetative growth and photosynthesis.

Figure 2 shows the relation between the growth stages of a peach fruit and the growth (in girth) of the tree. During the period from anthesis until the end of fresh-weight stage I (FW I) when lignin synthesis commences in the endocarp, the fruit and the tree grow simultaneously and presumably compete. Whilst lignin continues to be synthesized at an increasing rate during the remainder of dry weight stage I (DW I) secondary growth by the tree can not compete with growth of the stone in the fruit. Once the rate of fruit growth begins to decline in DW II, however, the secondary growth of the frame of the tree recommences. During this period the fruit is not competing with the frame of the tree since the decline in dry weight growth by the fruit is regulated by the seed (Chalmers and van den Ende 1977). The tree and fruit begin to compete once again at the start of DW III of fruit growth, when once again the rate of dry weight growth at the fruit increases and the rate of girth increase of the tree concomitantly declines.

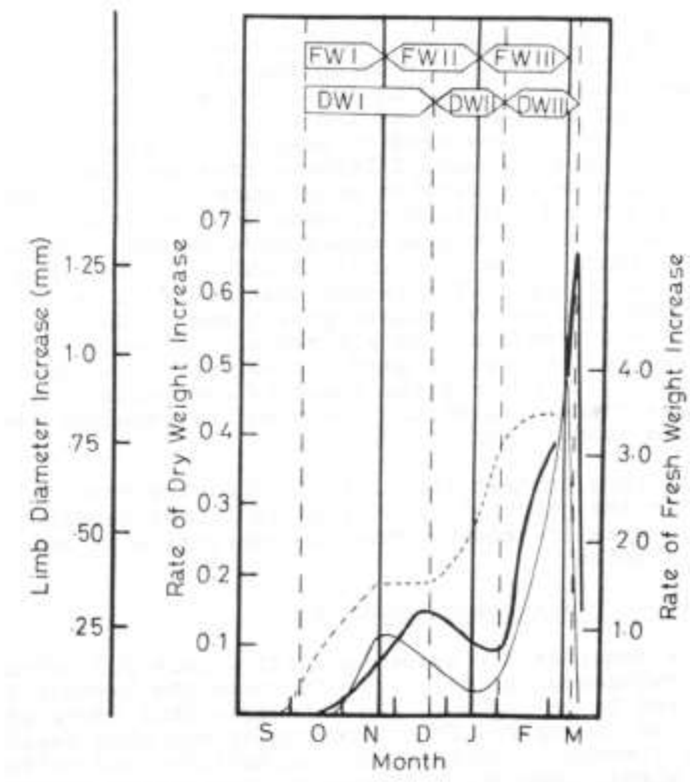

Fig. 2. Rate of fresh weight (_____) and dry weight (_____) growth of peach fruit compared with the cumulative increase in limb diameter (-------) during the growing season.

From an agronomic point of view this means that fruit growth could benefit if vegetative growth could be discouraged during DW I and DW III but not during DW II. Further, since the fruit do not compete with the tree during DW II (thus allowing secondary or girth growth to occur) one could suppress growth during this period without loss of the harvested crop.

In the experiment reported in table 3 these principles were put to the test in a field experiment. Self-rooted peach trees were planted at a very high density and were encouraged, with trickle irrigation to grow as fast as possible in year 1. From year two the rate of irrigation was reduced to limit vegetative growth by two different treatments.

TABLE 3. The effect of reduced irrigation on the control of tree size and fruit growth of peaches.

Irrigation treatment	Fruit volume increase (cm^3) during fruit growth stages			Tree growth	
	DW I	DW II	DW III	height (cm)	Butt area (cm^2)
Full daily	14.35 b	4.04 b	60.87 a	258 b	14.38 b
Reduced during DW II	13.77 b	2.53 a	74.31 b	259 b	12.12 ab
Reduced during DW II & III	11.3 a	3.09 ab	71.86 b	230 a	9.48 a

Values accompanied by a different letter significant by different at 5% level according to L.S.D.

Trees received only partial irrigation during DW II when lack of competition from fruit would have allowed unchecked growth by the tree.

Trees received partial irrigation throughout DW I and II. A large proportion of the unwanted vegetative growth occurs earlier, in spring than would be affected by treatment (i) and a more severe irrigation treatment would therefore check vegetative growth more effectively. Since less than 1/3 of the total fruit growth occurs before the start of DW III it was concluded that the loss in productivity resulting from reduced irrigation during FW I may not be significant. Further since checking vegetative growth reduces the potential for subsequent vegetative growth, fruit growth during DW III may be enhanced by reduced competition when all treatments received the same (full) allowance of water.

The results (Table 3) show that vegetative growth was suppressed by the treatments as expected. Fruit growth, also as expected was inhibited during DW I when growing actively but not during DW II when the growth rate of the fruit was declining. Finally growth of fruit was stimulated markedly by reduced competition from the tree when full irrigation was restored to the partial irrigation treatments. The net result of reduced irrigation in these treatments was to increase the harvested crop by 30% by both droughting treatments whilst simultaneously reducing vegetative growth in the most severe droughting treatment by 34%.

A similar management philosophy should be developed for pruning, fertilizing and perhaps even pathogen control whereby the amount of labour and materials used could be reduced to a minimum with little or no loss or perhaps even a gain in the productivity and manageability of orchards.

Increased productivity, Resources and the environment

a) Agricultural chemicals and fertilizers

No agricultural industry is more demanding of resources per unit of production than horticulture. For instance to produce a good peach or pear crop, orchards require between 300 and 600 kg/ha of Nitrogen per annum while at the same time requiring chemicals for pathogens, insect and weed control. There is scope for research to determine whether the levels of fertilizers and protectant materials applied in a single application are more than are needed for their particular purpose. It also seems that progress could be made in biological control of insect pests and pathogens.

Nevertheless pesticides, herbicides and fertilizers are vital to horticulture. If they were not used, the quantity and quality of fruit available for consumption would be substantially reduced. Fruit and other horticultural crops, while perhaps not necessary for our survival, fill an important role in the quality of our lives. To produce them requires heavy use of expensive, energy consuming and polluting chemicals. For this reason we may need to consider horticulture as a special case.

Whereas dry land forms of agriculture would need increased amounts of chemicals and resources to increase yields, it would reduce the unit consumption of materials and labour if tree crop yields were increased. The amount of spray chemicals consumed per ha, for instance, is related to the distance travelled by the spray cart and is unaffected by the number of fruit sprayed in the distance travelled. On the other hand the amount of elemental fertilizer required for fruit growth is a function of the number of fruit grown and although it will increase with production, it will decrease with yield provided the total amount of fruit grown does not increase. In most soil and orchard management systems, much fertilizer is wasted on weed or tree growth by poor placement and timing. As the cost of fertilizers and other chemicals increase in the future one might expect to see a resurgence of research studying the efficiency of fertilizer use.

Similar arguments can be made for the effect of increased yield on labour requirements and energy conservation in that the inputs required for producing a fruit crop are proportional to distance between individual fruit. It is not the fertilizer. spray or labour that goes into each fruit that determines the amount of the resource used, it is the amount that misses or is used travelling between them.

Factors Retarding the Adoption of Improved Technology

It is remarkable that an industry that has been subjected to so many pressures has made so little progress in the adoption of new technologies. Close planting, for instance, is so well tested and widely used to raise productivity in other countries such as Holland, Belgium, parts of Germany, Britain and the U.S.A. that it hardly qualifies to be called a new technology. The answer to the question, why our orcharding has been slow to adopt new technology is important enough to justify its own research study.

Yield of fruit from orchards at the Irrigation Research Institute, Tatura, like those in Holland, have doubled while the time required to obtain economic harvests has halved in the period between 1964 and 1978 but there is little or no evidence that a similar increase in productivity has occurred in private industry (Australian Bureau of Statistics 1977-78)*. While it is difficult to pinpoint the most important factors contributing to the widening technology gap, the following appear to be important.

Prospects and conditions in the industry

Orchardists have been uncertain of the prospects for sale of their products since late in the 1960's. This applies particularly to the growers of fruit for processing and fresh fruit for export, such as the fruitgrowers in the irrigation areas of Australia. On the other hand other fruit growing areas in Australia that do not have identical problems also appear to be reluctant to adopt advanced fruit growing methods. For instance fruit growers who have relocated their orchards because of urban development have no shortage of capital and by implication are confident in the industry's future. Yet these growers, who in addition to the above factors, are often starting over again with unplanted and often expensive land, still do not use modern orchard systems except perhaps to a certain extent for apples.

Ease with which Technology can be Adopted

Obviously if adopting a new technology only involves changing the rate or timing of an existing practice such as spraying, irrigating or fertilizing, or planting a new cultivar, it will be adopted by those orchardists who receive the information and believe in the advantages. At the other end of the scale, however, there are new technologies that involve a substantial departure from existing practices and management and these may be taken up only slowly and perhaps even reluctantly.

There is much horticultural technology in the latter category which requires a high level of input to implement. Fruit trees are perennial with woody frames that are amenable to manipulation and many options for growing them, some quite complicated, have developed.

Orchard Turnover

The fact that the orchard is perennial and even with the most radical orchard design requires 3-4 years to break even discourages technological innovation because a period of debt is entailed. Further there is no clear cut-off point beyond which the orchard will become unprofitable and will need to be replaced.

Fruit Statistics Australia 1977-78 Cat No 7303.0.

Cost of Action

The cost of removing and replanting orchard is high. Whatever orchard system is chosen, the orchardist faces a peak debt in the vicinity of $5000 - $8000 ha-1 before the orchard begins to reduce the debt.

Methods Used to Introduce Horticultural Technology into Industry

Whatever contribution the preceding factors make one can not escape the conclusion that research and extension workers in horticulture are to some extent responsible for the lack of technological progress in stone and pome fruit growing in Australia. The level of development reached by the fruit industry varies considerably from country to country but Australia just does not rank with other countries with similar levels of technological development.

Horticultural scientists and agronomists working in Australia lack commitment to, or enthusiasm for technologies with proven capacity to increase yield per ha and per dollar. I believe this stems from an inadequate understanding of the relationship between yield per ha and profitability, aggravated by confusion about the contribution improved productivity makes towards over-production.

Figure 3 relates to the first of these issues and shows the relation between gross margin ha-1 and yield for fruit crops in the Goulburn Valley in 1969-70. The same correlation undoubtedly still exists but the fact that more recent data was not available for this paper indicates that horticultural technologists are not particularly interested in this important relationship.

In the context of the latter issue, the terms of reference given to authors of invited papers at this conference implicitly questioned or sought us to question, the ethics and expense in nutrient, energy, environmental and human resources, of improving agricultural productivity. Although these questions are addressed to the cost rather than the need for increased productivity they form part of the overall debate that has generated the uncertainty in the minds of horticulturists (and agriculturists). In short, it has become fashionable for farmers, consultants, advisors, bureaucrats, and scientists to question the need for technological advance in agriculture where overproduction can so readily be achieved because for superficially convincing reasons, it is presumed that improved productivity will cause or exacerbate overproduction.

But high productivity does not mean high production. What, if any, contribution improved productivity makes to over-production needs to be clarified so that the resolve and objectives of the individuals and employers responsible for advising agricultural industries can be appropriately directed.

Conclusion

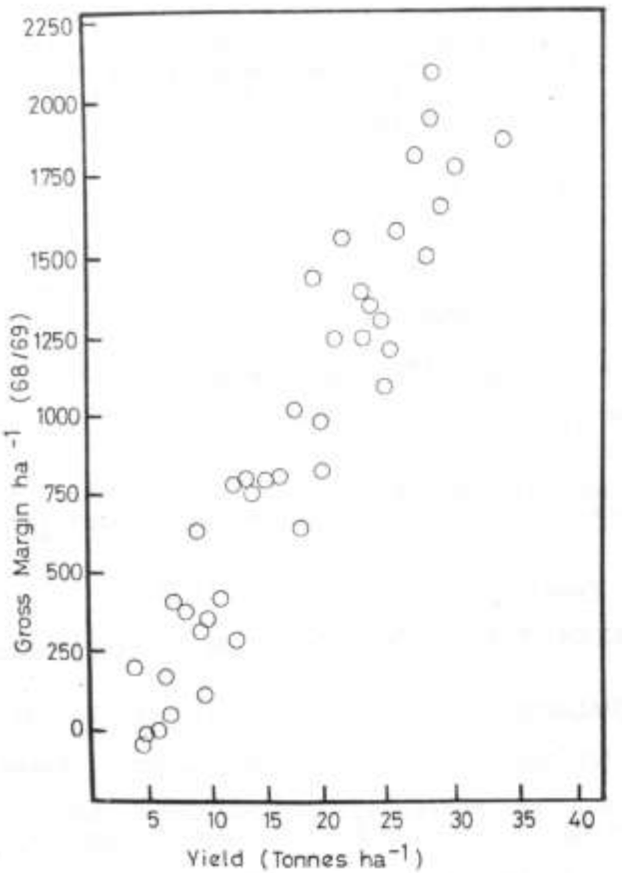

Fig. 3*. Gross margin per ha obtained for growing peaches in the Goulburn Valley. Victoria and 1968-69 in relation to yield per ha.

For a variety of reasons the culture of deciduous fruit crops for fresh fruit and processing markets is outdated and consequently there is great scope and need for improvement. Orchards are considered permanent or at least a long term investment and the attitude of all groups within the industry has become conditioned by this tradition. A significant improvement in productivity through better plant management will require a fundamental change in that philosophy. Trees have the capacity to crop when they are small and young and management practices need to be introduced and developed to take advantage of that fact.

*McColl, J.C. and associates. Benefit study of additional water allocation to various forms of farm development for State Rivers and Water Supply Commission.

Acknowledgement

I would like to thank Mr. J. Keatley of the Victorian Department of Agriculture and Mr. R. Sweedman of the N.S.W. Department of Agriculture for obtaining information on tree density and orchard development in their respective states.

1. CHALMERS, D.J., CANTERFORD, R.L., JERIE, P.H., JONES, T.R. and UGALDE, T.D. (1975). Austral. J. plant Physiol. 2: 635.

2. CHALMERS, D.J., and VAN DEN ENDE, B. (1975). Ann. Bot. 39: 423.

3. CHALMERS. D.J., and VAN DEN ENDE, B. (1977). Ann. Bot. 44: 707.

4. CHALMERS, D.J., (1978). Proc. Int. hort. Cong. XX: 1557.

5. CHALMERS, D.J., VAN DEN ENDE, B. and VAN HEEK, L.A.G. (1978). HortSci. 13: 157.

6. CLAYPOOL, .L., BEUTEL, J.A. and RIZZI, A.D. (1969). Rural Manpower Centre, Michigan State University report 16: 737.

7. DUNN, J.S. (1978). Proc. Int. hort. Cong XX: 1556.

8. ISSELL, L.G. and BOLCH, P.F. (1976). Victorian horticulture Digest 68: 7.

9. ISSELL, L.G. and CHALMERS, D.J. (1979). J. hort Sci, 54: 33.

10. JONES, T.R. (1971-72) Ann. Rpt. Hort Res Stn, Tatura, Victoria.

11. LUCKWILL, L.C. (1970). In: Physiology of Tree Crops, Luckwill, L.C. and Cutting, C.V., Eds. Academic Press London NY.

12. PROEBSTING, E.L. Jr. (1958). Proc. Am. Soc. hort. Sci. 71:103.

13. ROOSJE, G.S. (1970). Proc. N.Y. State Hort Soc. 115: 21.

14. VAN REEK. L.A.G. and GOULD, I.V. (1977). Austral J Exp Agric and Anim. Husb. 17: 346.