Innovative fruit production systems for peach and nectarine in Australia and Southeast Asia

R.J. Nissen[1], A.P. George[1], A. Lloyd[2] and G. Waite[1]

Abstract

New training and trellising systems are being developed for temperate fruits in Australia. The most productive and efficient trellising system with improved fruit quality appears to be the open Tatura system. Poor fruit size is a major problem of early-season cultivars. Crop-loading studies have established indices, such as fruit number per canopy surface and butt cross-sectional area, to provide a simple guide for optimum fruit thinning levels. Best management practices have been developed for the use of growth retardants, for optimising leaf nitrogen concentrations and for controlling rates of timing of irrigation. Regulated deficit irrigation (RDI) improves fruit sugar concentrations by restricting water application during stage II of fruit growth. RDI can also be used after harvest to restrict vegetative growth and enhance floral bud differentiation. New pest and disease control measures are being developed using a new generation of fruit fly bait products. These 'soft' insecticides, such as Spinosad (Dow AgroSciences), are used in significantly lower concentrations and have lower mammalian toxicity, than the organophosphates currently registered for use in baits in Australia. In addition to bait sprays, fruit fly exclusion netting has proven to be highly effective in eliminating fruit fly and many other insect pests from the orchard. This type of netting has been shown to increase sugar concentrations of peach and nectarine fruit by as much as 30%. Economic analyses have shown that the break-even point can be reduced from 10 to six years using these new production systems.

Introduction

Fruit quality is directly related to consumer satisfaction and purchasing patterns. Poor fruit size and quality are major problems in early-season, low-chill stone fruit cultivars. This has resulted in uneconomical and unstainable farming practices due to poor tree training, excessive crop loading, and incorrect management of pests, diseases, irrigation and nutrition.

In many fruit crops, approaches to improve light interception include planting design, pruning and tree training. These are critical determinants of tree productivity with internal tree shading severely reducing yield and fruit quality (Jackson, 1980; Palmer et al., 1992). Studies have shown that peach, nectarine and plum trees need good light penetration into the tree canopy with a minimum of 20% full sunlight transmitted to the fruiting sites. Arriving at the correct crop load level is critical with cropping capacity varying with tree age, variety and environment.

Management practices also directly impact on fruit size and quality and the interactions between vegetative growth, adequate nutrition, irrigation and pest and disease control practices are major determinants of fruit size and quality. One of the most serious pests of fruits and vegetables is the fruit fly (Tephritidae), which causes substantial losses in terms of both quantity and quality. Fruit flies are recognised worldwide as the major pest of horticultural production at both the commercial and subsistence levels, from the cold temperate regions of the globe to the heart of the tropics. Countries such as Thailand, Laos and Vietnam experience pre-harvest fruit and vegetable losses as high as 70–100%. As a result, fruit flies are seen as a major contributor to the ongoing problems of hunger, poor food nutrition and poverty, especially in rural communities. Thus, introduction of simple, practical, in-field solutions to the fruit fly problem will have a direct and positive influence on household food security for the rural citizens.

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Consumers are now requesting that their fruit and vegetables are grown in environmentally friendly systems. This impacts directly on the cost of production and growers not using best management practices will become unsustainable and, therefore, uneconomical. New production systems need to be fully tested and an economic evaluation carried out to determine their viability.

Orchard design and training systems

New planting systems and training systems have been developed to improve orchard production and efficiency. A major consideration in the design of these systems is the level of light interception into the tree canopy as this has a major impact on yield potential. Tree spacing and canopy characteristics (height, width, shape and leaf density) are elements which we can manipulate to capture a higher proportion of incoming light (Corelli and Sansavini, 1989). Economic fruit yields and quality are a function of the efficiency of light utilisation and distribution in the canopy (Jackson, 1980; 1985). Once a mature tree has filled the allotted space, excessive vegetative growth reduces light penetration into the canopy, affecting floral bud development, fruit set and fruit quality.

Close planting of trees, greater than 1000 trees per hectare under traditional orchard designs and training systems, results in poor light distribution and penetration into the canopy. These orchards become uneconomical within a short period of time. New orchard designs and training systems have been developed, which allow the close planting of trees that can double the yield per hectare.

Compared with central leader or free standing, vase trained trees, the open Tatura system produces greater cumulative yield during the first 3 years after planting (Van den Ende et al., 2001). The traditional vase trained trees, planted at low densities of less than 400 trees per hectare, can yield from 15 to 25 tonne per hectare. In contrast, the open Tatura system can produce yields as high as 40–50 tonne per hectare. The open Tatura training system provides the highest levels of light intercepted and transmitted through the canopy (Figs 1 and 2).

Crop loading and cultural practices

There are many indices or indicators of yield efficiency. These include:

- Yield per butt circumference
- Yield per butt cross-sectional area
- Yield per canopy surface area
- Yield per canopy volume, full and part cone

Yield efficiency based on a tree circumference or butt cross-sectional area are the most commonly used indicators for trees under the age of 5 years, but as a tree ages, other measures such as canopy surface area and canopy volume may be more appropriate. This is due to the effects of cultural practices, such as the use of growth retardants (eg paclobutrazol), which increase butt circumference, average fruit weight and consequently tree yield, but reduce vegetative growth, consequently reducing the yield efficiency expressed on a butt circumference or cross-sectional basis (Nissen et. al., 2002; Nardi 2001).

Our studies have shown that average fruit weight decreases rapidly with increasing crop loads but the rate of decline is reduced by applying additional

R.J. Nissen

Figure 1. Stone fruit trees trained onto the open Tatura trellis system.

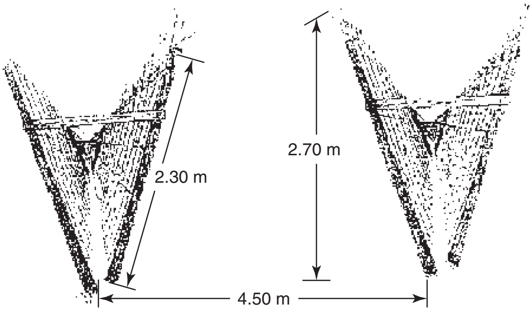

Figure 2. Dimensions and spacings for the open Tatura trellis system (Bas van den Ende 2001).

nitrogen and paclobutrazol because paclobutrazol alters the competition between vegetative and fruit growth in favour of the fruit. The pattern of decline in fruit weight is typical of almost all varieties, whether high- or low-chill. Growers of low-chill varieties leave about two fruit per centimetre of butt circumference (Fig. 3). However, based on the findings of our studies, we would recommend leaving either 20 fruit per sq metre of canopy surface area or 50 fruit per cubic metre of canopy volume

Cultural practices such as the use of paclobutrazol advance maturity by about 10 days and increase fruit size grades by between 1 and 2 grades thus significantly increasing monetary returns compared to untreated trees. Fruit sugar concentrations (total soluble solid) for low-chill stone fruit are low due to the short fruit development period. Studies by Nissen et. al. (2002) show that sugar concentrations of the fruit decrease by about 0.1° Brix for each increase of 10 fruit per tree. Paclobutrazol, when combined with additional nitrogen, improved sugar concentrations by about 1° Brix (Fig. 4). This synergistic response contradicts many other studies that have shown that nitrogen alone reduces sugar concentration.

Fruit firmness increases with increasing crop load, presumably due to a similar number of thicker-walled cells in smaller-sized fruit compared with large fruit. Paclobutrazol significantly increases fruit firmness due to a reduction in vegetative growth, enabling the fruit to compete more strongly for nutrients such as calcium and boron.

Our studies show that gross returns per tree increased up to normal crop loading levels (250 fruit per mature tree, 6 years of age, planted 3 × 4 m spacing × 2 m high). By increasing fruit number per tree up to 150% and 200% above the commercially accepted practice, returns increased slightly but fruit quality was severely affected. If we were to extend loading levels to 300% and 400% above normal crop loading levels, returns would decrease due to production of smaller, lower-quality fruit and increasing growing, harvesting and packaging costs.

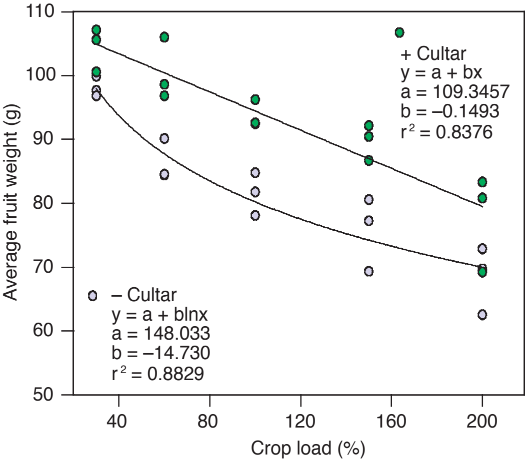

Figure 3. Effects of crop load and paclobutrazol on average fruit weight of cv. Flordaprince, Maroochy Research Station 1998.

However, it may not be possible to sustain such high crop load level in the long term. At high crop load levels, the higher percentage of smaller, poorer-quality fruit may deplete trees of their carbohydrate and nutrient reserves leading to biennial bearing. At very heavy crop load levels this may even lead to tree death. At 200% crop load level the percentage starch decreased by 30% in the shoots (Fig. 5).

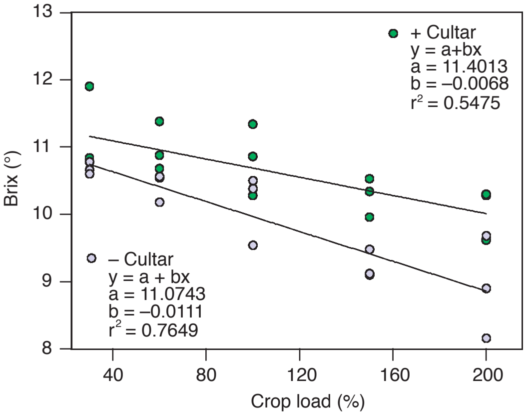

Figure 4. Effects of crop load and paclobutrazol on Brix concentration (°) of cv. Flordaprince, Maroochy Research Station 1998.

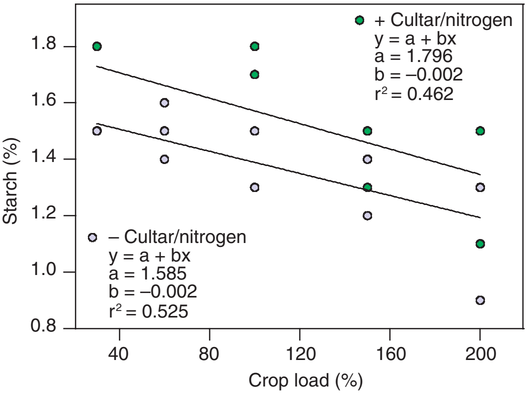

Figure 5. Effects of crop load and management treatments on shoot starch concentrations.

Irrigation

The water use over a season relates closely to the development stage of the tree — both canopy coverage and the fruit growth stage. The development pattern is vital to understanding the sensitivity to water and other stresses. The water use, and therefore irrigation requirements, for stone fruit are greatly influenced by the fruit growth curve (Fig. 6). Large-scale irrigation systems are not required to produce high-value horticulture crops. Direct pumping and small reservoirs, weirs, bores and wells, etc., are more appropriate. Table 1 provides a broad annual guide to water requirements for bearing trees (Year 2 and onwards) on a palmette system in coastal Australia.

For management reasons, irrigation requirement may be different from total tree water use. For example, excessive vegetative vigour can be controlled by restricting irrigation at the critical period during fruit development and after harvest. This irrigation management is termed 'regulated deficit irrigation' (RDI). In much of Southeast Asia, water deficits will occur in at least 4 months each year and irrigation will be essential for good commercial production. For early-maturing, low-chill stone fruit cultivars, due to their shorter fruit development period and a truncated stage two of fruit growth, RDI may be less effective. Also, in eastern Australia, the summer rainfall pattern coincides with the fruit development period of low-chill cultivars and this would make RDI difficult to implement. For countries such as Thailand, because the 'dry season' coincides with the flowering and fruit development period, regulated deficit irrigation may be feasible.

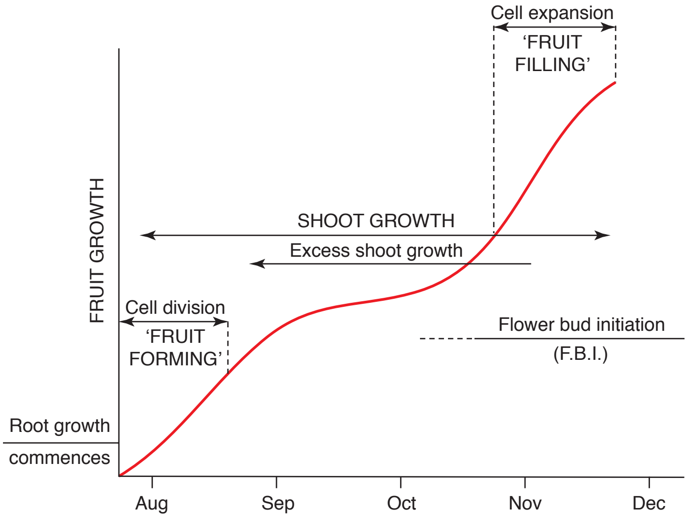

Figure 6. Idealised growth pattern for a later maturing, low-chill peach or nectarine (adapted from Menzies 1992).

Table 1. Water requirements for bearing trees in Australia (ignoring rainfall).

Month	Stage of growth	mm per week	Litres per tree per week
August (winter)	Dormancy	15	150
September (spring)	flowering/early fruit set	20	300
October (spring)	Harvesting	25–30	350
November (early summer)	Harvesting	30	250
December (mid summer)	floral initiation	25	250
January (late summer)	Completion of vegetative flush	20	200
February (early autumn)	Hardening off flush	25	200
March (mid-autumn)	Hardening off flush	20	200
April to July (late autumn)	Leaf senescence/early dormancy	no irrigation necessary	no irrigation necessary

Initial studies were conducted to determine if RDI could be used with low-chill cultivars with much shorter fruit development periods (80–120 days). Our results indicate that mild to moderate water stress (up to −50 kPa) may be beneficial if applied just prior to stone-hardening, after the completion of the cell division period and up to 3 weeks prior to harvest, particularly in warm–subtropical regions where fruit growth in the final stage is excessive. However the short fruit development period of early-season, low-chill cultivars may limit the period to which the RDI can be applied to about 30 days, and for later-season chill cultivars to about 45–50 days.

Further studies are needed to evaluate higher soil moisture stress levels (–50–200 kPa), similar to those used with high-chill cultivars in Victoria, and a longer duration of stress from flowering to the end of stage two of fruit growth. Preliminary evaluation on light clay soils in Thailand indicates that soil moisture stress levels up to −200 kPa reduced yield and fruit firmness by about 20% but fruit sugar concentrations were increased by a similar 2–3° Brix (Noppakoonwong et al., 2002). The maximum stress level where there appeared to be little or no effect on fruit growth was achieved at about −80kPa.

For low-chill varieties, RDI may have a greater application to control excessive growth after harvest. Further studies are needed to elucidate these effects. Table 2 presents the critical application times and minimum watering rates for hill tribe villages in northern Thailand using principles of deficit irrigation.

New pest control measures

Species of fruit fly

The major species of fruit fly present in Australia are: Queensland fruit fly, Mediterranean fruit fly, and Papaya fruit fly. The major species of fruit fly in Thailand is *Bactrocera dorsalis*. In Thailand, the usual control measure is to bag the fruit before it starts to colour. The fruit fly species of greatest economic importance in the north of Vietnam are *Bactrocera dorsalis*, *B. correcta*, *B. pyrifoliae*, *B. cucurbitae*, *B. tau* and *B. latifrons*. In the south of Vietnam the most important species are: *Bactrocera dorsalis*, *B. correcta*, *B. cucurbitae*, *B. tau* and *B. carambolae*.

In Australia, cover sprays of persistent insecticides, such as fenthion, are applied to control fruit fly. This causes environmental problems through leaving chemical residues on the fruit and in the environment. This problem would be exacerbated in Vietnam because of the extensive network of canals and watercourses throughout the farming districts and the use of these watercourses for producing other food supplies, bathing, washing clothes, etc.

There are several ways to monitor fruit flies and the best strategy uses a combination of these techniques. The methods are:

- Fruit fly traps (male pheromone used as an attractant, these need checking regularly)
- Visual monitoring
  - checks made of fruit and foliage for adult flies
  - fruit sampling, monitoring of early-set fruit for stings and eggs under the surface.

Cover sprays

Two broad-spectrum insecticides are normally used to control fruit fly. These are fenthion and dimethoate. Both these chemicals have been widely used for fruit fly control for many years but in recent years there has been a strong move to develop alternative treatments. This has been driven by consumer and environmental concerns over pesticide usage and residues, problems associated with long withholding periods which interfere with harvesting, and the fact that broad spectrum insecticides are detrimental to beneficial insects and are therefore not compatible with Integrated Pest Management (IPM) programs. Another concern is uncertainty about the long-term availability of the currently used chemicals.

Table 2. Water requirements for bearing trees (3 years and older) in northern Thailand with no rainfall using deficit irrigation. Trees are watered at a minimum of four critical times; all trees are heavily mulched to conserve moisture.

Season	Months	Plant growth stages	Minutes of watering by hand-held hose	Number of 10-litre buckets	Litres of water per tree
Winter	November–December	Dormancy		No irrigation necessary	
Dry	December–January	Flowering	7–8	15	150
Dry	February–March	2–3 weeks after flowering	7–8	15	150
Hot	March–April	4 weeks before harvest	10–12	20	200
Hot	May–June	two weeks before harvest	7–8	15	150
Wet	June–October	Vegetative Growth		No irrigation necessary	

Various natural products such as neem oil and natural pyrethrum have been investigated as cover sprays or repellents for fruit fly control but none has proven to be particularly effective. New generation bait products based on ‘soft’ insecticides are being developed. These are used in much lower concentrations and have much lower mammalian toxicity than the organophosphate insecticides registered for use in baits in Australia. The new generation, microbially produced insecticide, Spinosad (Dow AgroSciences), which has obtained organic certification in the US, appears to offer the best prospect as a new cover spray treatment for fruit flies. However, further research is needed on Spinosad to determine its effective application rates.

Protein baiting

As an alternative to cover sprays, fruit fly may be controlled by applying bait sprays. The advantage of bait sprays is that they are only applied to a small part of the tree, such as the trunk or foliage. Consequently, insecticide residues are not left on the fruit. Bait sprays consist of a combination of an insecticide, eg chlorpyrifos, plus an attractant for fruit fly, eg yeast autolysate. About 50 ml of the mixture is applied to the lower leaves of each tree every 7 days and reapplied after rain. If fruit fly infestation is high, bait spraying may need to be switched to cover sprays (spray the whole tree) of fenthion or trichlorfon. Trees are sprayed every 7 days until harvest. A suggested application schedule for Thailand is presented in Figure 7.

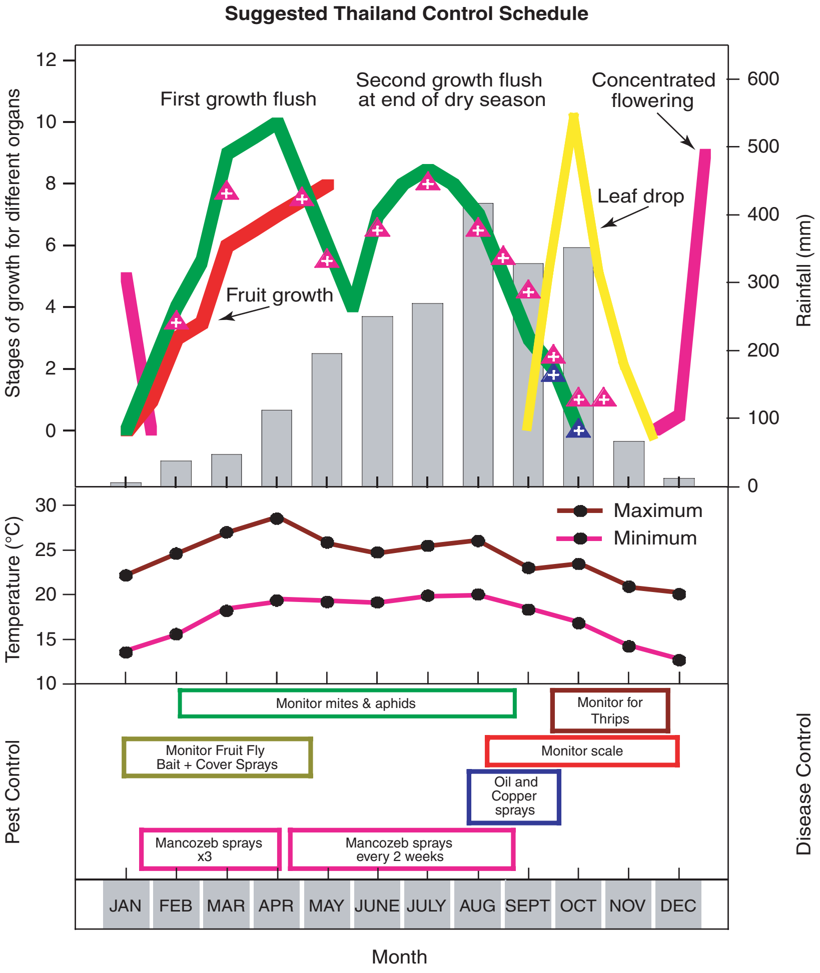

Figure 7. Suggested application schedule to control fruit fly in stone fruit orchards in Thailand.

Two new commercial baits include attractant protein sources mixed with insecticides Spinosad (Dow AgroSciences) or fipronil (BASF) as insect toxicants. DPIF researchers are developing these new baits to provide the same level of control for Queensland fruit fly as currently used standard bait. The new baits are applied at lower rates (5–7 L/ha) than standard baits, which are applied at 15–30 L/ha, depending on the crop type. Both bait formulations include thickening agents which prolong the effective life of the bait on foliage but current recommendations are that the baits should still be applied on a weekly basis, the same as the standard bait.

Physical barriers

Physical barriers that exclude the adult insect and thereby prevent oviposition into fruit provide a non-chemical method of control. These are highly suitable for both conventional and organic production on a number of different scales. On the smallest scale, applicable to organic home gardeners, various types of bags can be used to completely enclose individual fruit to protect them from fruit fly and other insect pest damage.

On a larger scale, small mesh net fabric can be used to fully enclose individual trees when fruit are susceptible to attack. A 2 mm mesh net made from long lasting, translucent fibre that minimises the shading factor has been used to exclude fruit flies and a variety of other insect pests such as macadamia nut borer, fruit spotting bug, fruit piercing moth, and yellow peach moth. Provided the net is correctly erected and maintained, this technology has the potential to significantly reduce pesticide usage in conventional production, and to provide a practical and appropriate method for organic pest control in a range of crops.

Exclusion netting involves a high initial capital cost and it will not be appropriate for all crops, but in some crops where conventional hail/bird/bat netting is already being extensively used (eg stone fruit, pome-fruit, kiwifruit, persimmon), it will provide new options for both conventional and organic producers at relatively little extra cost. Recent trials over 2 seasons at Maroochy Research Station, Nambour, Queensland compared fruit fly infestation in peaches under exclusion netting (with no additional fruit fly treatment) to that in an adjacent block under conventional hail net (Figs 8 and 9).

Fruit fly trap catches in the area during the trials ranged from 50–350 flies per trap per week. Infestation levels under exclusion netting were zero in both seasons. The infestation level in the chemically treated block was zero in the first year (Fig. 10) and 0.25% in the second year. As well as the economic viability, the researchers also investigated the effects of this small mesh size on environmental conditions and crop parameters under the net. Preliminary results indicate that fruit quality and yields can be significantly increased under the exclusion netting. Fruit maturity is advanced by about 7–10 days due the higher heat units accumulated under the netting.

Figure 8. Close up of the 2 mm translucent monofilament fibre exclusion netting.

R.J. Nissen

Figure 9. View of Maroochy Research Station stone fruit trial blocks with total exclusion net (white) and bird and bat net (black).

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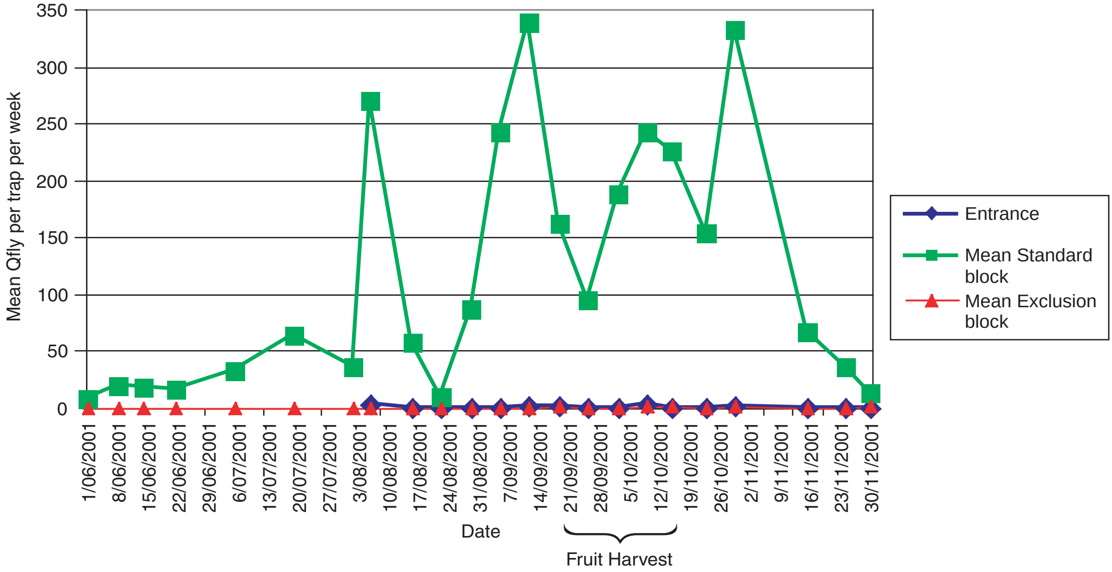

Figure 10. Fruit fly trap catches in stone fruit in 2001.

Particle film technologies

A new kaolinite product Surround™ has been developed in the USA for protecting fruit crops from heat stress, sunburn and frost. This product can also be used as a biopesticide. Due to its ability to reduce heat stress on the tree, Surround™ can improve photosynthesis, fruit size and fruit set. It can also improve fruit colour due to a greater proportion of transmitted and diffuse light within the canopy. In the USA, it is reported to control leafrollers and leafhoppers and to suppress mites, codling moth, plum curculio, apple sucker, stinkbugs, apple maggot and thrips. Surround® is sprayed on as a liquid, which evaporates, leaving a protective powdery film on the surfaces of leaves, stems, and fruit. Conventional spray equipment can be used and full coverage is important. The film works to deter insects in several ways. Tiny particles of the clay attach to the insects when they contact the tree, agitating and repelling them. Even if particles do not attach to their bodies, the insects find the coated plant or fruit unsuitable for feeding and egg-laying. In addition, the highly reflective white coating makes the tree less recognisable as a host (Dufour, 2001; McBride, 2000).

Trials with Surround® in Israel on nectarines have shown that female Mediterranean fruit flies avoided landing on treated fruits and no infestations occurred (Mazor and Erez, 2004). Similarly, Saour and Makee (2004) found kaolin film effectively controlled olive fruit fly (*Bactrocersa oleae*) in olives. Results showed successful season-long suppression of *B. oleae* compared to insecticide sprays of dimethoate that failed to protect olives for the same period after the last spray application (Saour and Makee, 2004). Due to the completely dry fruit development period in Thailand, Surround® may act as a highly effective protectant of temperate fruits. Surround® can be washed off by heavy rain and has to be reapplied, so its usefulness in high rainfall regions is limited, but in areas of low rainfall this technology would be highly applicable and beneficial.

Economic evaluation

New innovative production systems for stone fruit tested at Maroochy Research Station were evaluated for their economic viability using economic analysis programs. Market prices are highly volatile. Variation between seasons and within seasons significantly affects profitability so price data was collated from years 1996 to 2000 and averaged, then used in the analysis. Industry standard training systems were evaluated for a non-netted and netted orchards (Table 3).

Table 3. Comparison of tree number per hectare under different training systems.

Training system	Tree spacing (m)	Tree number per hectare
Tight vase	3	833
Palmette	3	1111
Open Tatura	1	2222

Development, fixed, variable and capital costs were adjusted for each training system and a discounted accumulated cash flow generated.

Our findings show that non-netted orchards will be non-viable. The greatest impact on the break-even point is the number of trees planted per hectare. This is due to increases in productivity (yield). Comparing total exclusion-netted orchards under an open Tatura system to a tight vase system, the break-even point is advanced by about three years. Comparing a total exclusion netted orchard under an open Tatura system to a palmette system, the break-even point is advanced by four years (Figs 11 and 12).

An increase in market access has not been accounted for in this economic analysis. A significant increase in the number of potential markets, due to fruit fly freedom status, is a major benefit of utilising total exclusion netting. Also, significant benefits due to decreased use of pesticides, providing consumers with a clean green product may realise increased returns.

In conclusion, this analysis of total exclusion netting has shown that the extra costs associated with enclosing a stone fruit orchard under such a netting structure did not reduce its viability. To recover the higher cost of a total exclusion netting system, growers must use high-density, high-yielding plantings such as open Tatura and best management practices.

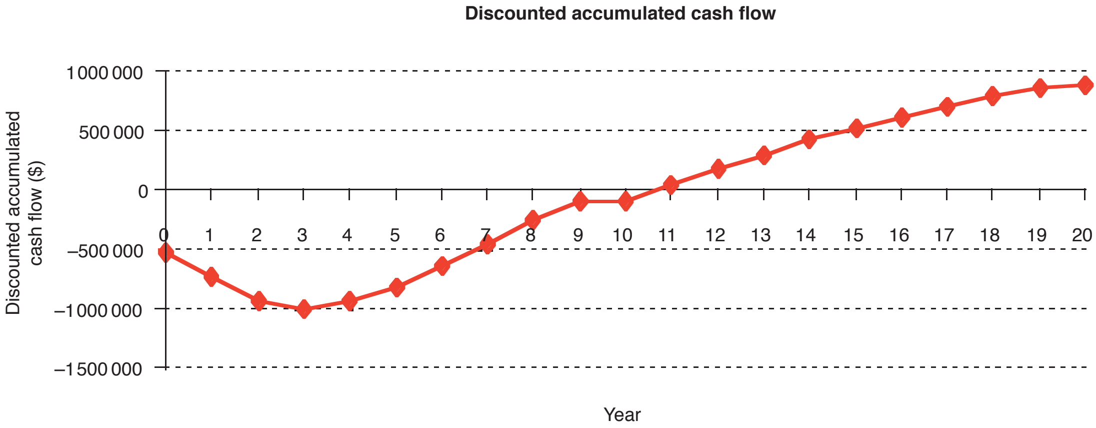

Figure 11. Discounted accumulated cash flow of palmette system under total exclusion netting.

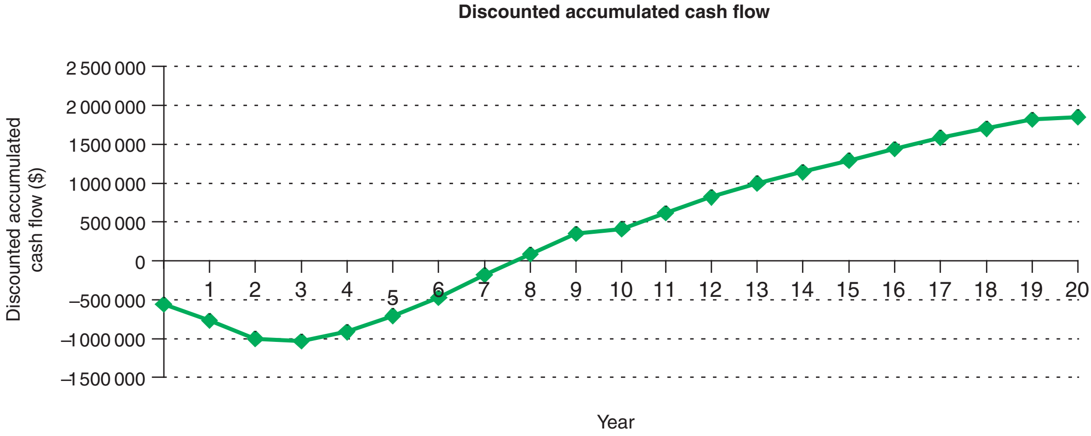

Figure 12. Discounted accumulated cash flow under total exclusion netting for open Tatura stone fruit orchard.

References

Corelli L. and Sansavini S. 1989. Light interception and photosynthesis related to planting density and canopy management. Acta Horticulturae 234, 159–174.

Dufour R. 2001. Insect IPM. In 'Apples; Kaolin Clay; Reduce-risk pest control.' Factsheet. Appropriate technology transfer for Rural Areas, [Online], 4 pages, Available: http://attra.ncat.org/attra-pub/kaolin-clay-apples.html. [March 19 2004].

Jackson J.E. 1980. Light interception and utilisation by orchard systems. Horticultural reviews Vol 2. (ed. J. Janick), pp. 208–267. The AVI Publishing company Inc: Westpoint Connecticut.

Jackson J.E. 1985. Future fruit orchard design: economics and biology. In 'Trees as crop plants'. (eds. MGR Cannell and J.E. Jackson), pp. 441–459. Institute of Terrestrial Ecology: Huntington, UK.

Mazor M. and Erez A. 2004. Processed kaolin protects fruits from Mediterranean fruit fly infestations. Crop Protection 23, Issues 1, 47–51.

McBride J. 2000. Whitewashing Agriculture. Agriculture Research Services [Online], 9 pages, Available: http://www.ars.usda.gov/is/AR/archive/nov00/white1100.htm. [2004, March 19].

Nardi D. 2001. Regional Reports, Victoria. Australian Fresh Stone Fruit Quarterly 3(3), 21–22.

Nissen R.J., George, A.P., Menzies, R. and Bruun D. 2002. Sub Project: Crop Loading of Low-Chill Stone Fruit Report. 2002. In: Crop regulation and blossom thinning to increase fruit size and market returns. Final report for Horticulture Australia Ltd., Project no. SF 97007.

Noppakoonwong U., Sripinta P., Pasopa P. and Pichakum A. 2002. Effects of water stress on shoot growth and fruit development of nectarine. Reports of the First International Workshop on Production Technologies for Low-chill Temperate Fruits, Chiangmai, Thailand, (ed. S. Subhadrabandhu), pp. 236–243.

Palmer J.W., Avery D.J. and Wertheim S.J. 1992. Effects of apple tree spacing and summer pruning on leaf area distribution and light interception. Scientia Horticulturae 52, 303–312.

Saour G. and Makee H. 2004. A kaolin-based particle film for suppression of olive fruit fly *Bactrocera oleae* Gmein (Dip., Tephritidae) in olive groves. Journal of Applied Entomology 128, 28–31.

Van Den Ende B., Clippingdale B. and Corboy P. 2001. Effects of tree density and training systems for peaches, apricots and plums. Final report for Horticulture Australia Ltd.