# An investigation of low-cost protective cropping

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# Summary

Increased climate variability is a key challenge facing the Australian vegetable industry. Heat waves, heavy rain, unseasonal frosts, hail and other extreme weather events can reduce quality at least, and result in total crop write-off in severe situations. Such events threaten the viability of vegetable farms and impact supply to customers and consumers, creating issues throughout the supply chain.

Technological solutions such as high-tech greenhouses can provide a level of control and certainty. However, the expense of such structures is not justified by returns for many vegetable crops, which can be relatively low value, space consuming, or simply not suited to full protective cultivation. Low cost protected cropping offers a compromise between the cost of high technology and the need to provide some protection to crops from adverse conditions.

An initial review identified shade structures, wind-breaks and floating row covers as the most potentially effective options for vegetable growers. These were subsequently trialed in a large number of growing sites around Australia.

Permanent shade houses and nets can provide full protection from events such as a hailstorm, but were unable to withstand cyclonic conditions in WA. They did not greatly reduce crop temperatures when used as a top-only system. Although yield was unaffected by shading in these trials, it was noted that red shading resulted in darker leaf colour. Capsicum plants grown in the retractable roof Cravo® house were significantly larger and healthier than similar plants grown outside, and would be expected to have greatly increased yield over an extended cropping period.

Using floating row covers for summer production of leafy greens demonstrated a number of potential issues with such systems. These included the difficulty of weed control as well as the potential for small insects such as aphids to multiply inside the protective cover if the sides were not kept well sealed. Floating covers can improve seed germination if conditions are sub-optimal. However, if the crop is well managed then there may be no benefit.

Under cold conditions, however, 'fleece' floating row covers can provide major benefits. These materials can significantly improve germination and growth and protect crops from light frosts. Harvest of lettuce was brought forward 1-2 weeks using fleece materials. The lightest fabrics, which are also the cheapest, were sufficiently durable and gave results as good or better than more heavyweight fleeces.

Capsicum plants grown under floating row covers had improved yield and better fruit quality. Floating row covers enhanced plant growth, prevented sunburn and reduced temperatures around the plants during hot weather. They also proved effective at excluding Queensland fruit fly, a major pest of capsicums. The results were best when the row covers were installed early during development.

The same effects, however, were not observed for chilli plants. No increases in either yield or quality were observed for cayenne or birds-eye chillies grown with floating covers. The large size of the plants and more frequent harvests also made use of floating covers problematic for chilli production. However, the materials did provide a significant benefit by excluding fruit fly, which may be important for growers practicing IPM.

The next steps should focus around floating row covers and retractable roof structures, both of which show considerable promise, but for which questions remain. The trials of capsicums under retractable

roof structures should be repeated as the impressive plant growth improvement under these structures was not transplanted into higher yield, suggesting something like water or nutrient availability was limiting yield.

The floating row covers were very promising in alleviating the effects of extreme heat and cold in babyleaf spinach crops. There are more questioned to be answered in relation to this crop group, and floating row covers should be evaluated more thoroughly on baby leaf crops and other leafy vegetables such as head lettuce and Asian greens. The conflicting results with floating row covers on capsicums v's chillies also warrants further investigation. The impact on Queensland fruit fly control could be a major step forward in the management of that serious pest in capsicums and again requires more research.

# Keywords

Floating row cover, cover, netting, shade, retractable roof, greenhouse, insect net, fleece, frost, fruit fly, protective structure, plasticulture, capsicum, chilli, baby-leaf, lettuce, spinach

# Introduction

Increased climate variability is one of the key threats to the Australian vegetable industry. Heat waves, heavy rain, unseasonal frosts, hail and other extreme weather events can reduce quality at least, and result in total crop write-off in severe situations. Such events threaten the viability of vegetable farms in all of the growing regions. They can also impact supply to customers and consumers, creating issues throughout the supply chain.

Greenhouses can provide everything from a simple shelter to full environmental control. Such new technologies can offer not only improved productivity, but also a degree of certainty in production outcomes. However, this comes at a significant cost. Many vegetable crops are relatively low value, or require large amounts of space. The expense of establishing a full, climate-controlled greenhouse for such crops cannot be justified by returns. Moreover, such technological solutions do not suit every situation, every crop, or every grower.

Low cost protective structures, as used in other horticultural sectors, can potentially fill the gap between open field production and a full controlled environment. Net houses, wind-breaks and even simple floating row covers, can provide plants with some protection from the elements. They may also have benefits in terms of improved quality, better pest management, reduced contamination of the harvested product and extension of the normal growing season. Even though the system may be primarily designed to prevent total loss in the event of a major climate event, such additional benefits may help justify their expense.

This report details the results of trials around Australia examining the use of low cost protected cropping options for vegetable production. Trials were conducted in many of the major centres for vegetable production, and focused on crops and seasons where adverse weather conditions were most likely to affect production. A total of 10 different locations were used (Figure 1), growing a range of crops including baby-leaf, lettuce, capsicums and chillies and eggplant (NT).


**Figure 1. Locations of trial sites around Australia. Results are presented for protected cropping options from all sites except Darwin, where trials are ongoing.**

Not all of the options proved successful. In some cases, the lack of a major weather event meant that there was no benefit from a structure. In others, the climate event was so severe the low cost option proved inadequate.

However, some results were positive results. Floating row covers, whether netting or spun-bonded polypropylene (frost cloth), proved to have benefits in a range of situations. Such materials are increasingly used in the UK and Europe. This means material costs are decreasing and mechanised systems are available to apply over large areas. As one of the least expensive options available, they would seem to have real potential for increased application in the Australian environment.

# Methodology

## Desktop review

The potential for low cost protected cropping of Australian vegetables was initially investigated through a desk-top review. Issues examined included the use of different materials for managing temperature extremes, excluding pests and protecting plants from damaging wind and rain. The review identified the protected cropping options that appeared to have the best potential for cost effective use by vegetable growers.

These recommendations were used to formulate the trials conducted in the following stages of the project. Regions selected included those at risk of climate extremes or which were limited by seasonal temperature growing restrictions. In most trials, air temperature and humidity were recorded underneath and outside the protective structure/cover. Crops were assessed for yield and quality, and in some cases, insect numbers were measured underneath row covers. Trials were grouped according to the protective material used and/or the purpose for protecting the crop.

## Permanent shade houses and nets

Options assessed included hail netting, insect-proof netting and retractable roof Cravo® greenhouse. The effectiveness of these options at protecting crops from extreme weather events, insects and heat over summer were assessed. Temperature and humidity loggers were installed under and outside of existing structures and crop yield and quality was assessed at commercial harvest.

Yield was assessed for baby-leaf lettuce and spinach crops inside and outside shade structures. Harvested quadrants were weighed and their storage life assessed. Insect populations within the crop were estimated by vacuuming a measured area for a fixed time with a blower-vacuum.

In the case of capsicum crops, yield was assessed by strip picking plants at commercial maturity. Fruit were weighed and assessed for colour and marketability.

**Table 1. Summary of trials examining permanent structures**

| Netting/structure | Location | Season | Crop |
|---|---|---|---|
| Hail net | Tolga, QLD | Summer 2014-15 | Hydro-lettuce |
| Hail net and Insect Net | Stanthorpe, QLD | Summer 2014-15 | Spinach |
| White / red shade netting | Bairnsdale, VIC | Summer 2014-15 | Baby-leaf spinach |
| Shade netting | Carnarvon, WA | Summer 2014-15 | Capsicum |
| Shade netting | Meadows, Adelaide Hills | Summer 2014-15 | Non-crop |
| Cravo® house | Bundaberg, QLD | Spring 2015 | Capsicum |

## Floating row covers for summer production

Floating row covers may be used during summer to protect crops from high temperatures, sunburn and insect pests as well as to reduce evaporation from both plants and soil. A range of different materials were evaluated for warm weather production of leafy greens in NSW and Victoria. These included netting materials such as InsulNet, VegeNet and fine weave Insect Net. A number of different non-woven spun-bonded polypropylene materials – often described as 'fleece' – were also tested. Even though fleece is primarily intended for cold weather protection, it provides a full barrier against insects while still being permeable to air and moisture.

Replicate units of each material were installed over freshly sown vegetable crops and the edges secured with shovelfuls of soil. Assessments included temperature, humidity and yield under the floating covers compared to the uncovered field. Harvested quadrants of babyleaf vegetables were weighed and their storage life assessed. Lettuces were counted or individually weighed. Insect populations within the crop were estimated by vacuuming a measured area for a fixed time with a blower-vacuum.

**Table 2. Summary of trials on floating row covers for summer production of leafy vegetables**

| Netting | Location | Season | Crop |
|---|---|---|---|
| Insulnet, VegeNet, Groshield | Robinvale, VIC | Autumn 2015 | Direct-seeded lettuce |
| Insulnet | Camden, NSW | Summer 2014-15 | Direct-seeded baby spinach |
| VegeNet, Insect Net | Camden, NSW | Autumn 2015 | Direct-seeded baby spinach |
| VegeNet, Insect Net, Fleece | Camden, NSW | Autumn 2015 | Direct-seeded baby spinach |
| VegeNet | Werribee, VIC | Summer 2015-16 | Cos lettuce |
| VegeNet, Fleece, Aphid Net | Bairnsdale, VIC | Summer 2015-16 | Direct-seeded baby-leaf lettuce |

## Floating row covers for winter production

Whereas floating covers in summer are primarily applied to maintain soil moisture, prevent sun damage and protect crops from pests, during winter the same materials may be applied to raise temperatures around the crop and protect from harsh winter wind and rain. Fleece covers ranging from 17 to 50g/$m^2$ were tested in Werribee, Victoria and Camden, NSW. The covers were installed over freshly sown vegetable crops and the edges secured with shovelfuls of soil. Assessments included air temperature, soil temperature, humidity and yield under the floating covers compared to the uncovered field. Harvested quadrants were counted or weighed and their storage life assessed. Lettuces were counted or individually weighed. Insect populations within the crop were estimated by vacuuming a measured area for a fixed time with a blower-vacuum.

**Table 3. Summary of trials on floating row covers for winter production of leafy vegetables**

| Netting | Location | Season | Crop |
|---|---|---|---|
| Fleece; Groshield, Elders | Werribee, VIC | Winter 2015 | Cos lettuce transplants |
| Fleece; Groshield, Agryl, Elders fleece | Camden, NSW | Winter 2015 | Direct-seeded oakleaf lettuce |

## Floating row covers for production of fruiting vegetables

Whereas the objective with leafy vegetables is to increase vegetative growth, treatments to increase fruit development may be quite different. Control of fruit fly presents a further challenge. Floating row covers were evaluated for production of capsicums in Silverdale, NSW and Bundaberg, Queensland. Nets were generally applied soon after transplanting or before fruit set. One trial also examined the effectiveness of VegeNet applied at different times during crop development.

Assessments included temperature, humidity, and presence of insects. Fruit fly ingress into the cropping area or under the nets was evaluated using Biotraps baited with cuelure wafers. In some cases, vegetative growth was recorded by weighing whole plants. Yield was estimated by strip-picking plants at various stages of maturity. Capsicums were then assessed in terms of weight, number, colour, overall marketability and pest damage.

Similar trials were conducted on chilli plants. Although the same species as capsicums, chilli fruit and plants are quite different. Control of fruit flies on chillies is particularly challenging. Trials examined use of netting materials to exclude fruit flies from chilli crops, as well as the effects on quality and yield.

**Table 4. Summary of trials on floating row covers for production of fruiting vegetables**

| Netting | Location | Season | Crop |
|---|---|---|---|
| VegeNet | Silverdale, NSW | Summer 2014-15 | Capsicum |
| VegeNet, Insect Net | Bundaberg, QLD | Autumn 2015 | Capsicum |
| VegeNet, Fleece | Bundaberg, QLD | Winter/Spring 2015 | Capsicum |
| VegeNet applied at flowering, fruiting and pre-harvest | Bundaberg, QLD | Summer 2015-16 | Capsicum |
| VegeNet, Vent Net, Aphid Net | Silverdale, NSW | Summer 2015-16 | Chilli |
| VegeNet | Bundaberg, QLD | Summer 2015-16 | Chilli |

All data was analysed using CoStat to determine significant differences between values.

# Outputs

## Presentations / workshops

### *Completed*

| | | |
|---|---|---|
| Lindenow, Vic | 9 September 2015 | Reducing contaminants in leafy vegetables |
| Gatton, Qld | 26 August 2015 | Application of floating row covers to leafy vegetables, controlling contaminants in harvested vegetables |
| Cranbourne, Vic | 11 September 2015 | Reducing contaminants in leafy vegetables |
| Wanneroo, WA | 2 October 2015 | Application of floating row covers to leafy vegetables, controlling contaminants in harvested vegetables |
| Bundaberg, Qld | 22 October 2014 | Using netting to improve yield and quality of capsicum (district agronomists) |
| | 21 November 2014 | Using netting to manage fruit fly on capsicum crops (fruit fly forum) |
| | 20 May 2015 | Using fleece and netting to improve yield and quality of vegetable crops (district agronomists) |
| | 9 December 2015 | Using netting to manage fruit fly on capsicum crops (fruit fly forum) |
| Brisbane, Qld | 25-27 June | National Hort Convention, low cost protected cropping options for vegetable growers |
| Cowra, NSW | 26 April 2016 | Netting and fleece for production of babyleaf vegetables |

### *Ongoing*

| | | |
|---|---|---|
| Darwin, NT | 20 May 2016 | Low cost protected cropping options for vegetables |
| Brisbane, Qld | 23-25 June 2016 | National Hort Convention, display and materials on low cost protected cropping options for vegetable growers |
| WEBINAR | July 6 2016 | Low cost protected cropping options for vegetables |
| Werribee, Vic | 11 August 2016 | Farm walk Werribee, use of frost protection fleeces for vegetable crops |
| Sydney | October 2016 | Using IPM in protected cropping – Physical barriers |
| Manjimup, WA | October 2016 | Low cost protected cropping options for vegetables |
| Cairns, Qld | 20-25 November 2016 | Presentation at the International Symposium on Protected Cultivation in Tropical and Temperature climates (paper |

submitted, Acta Hort publication in preparation)

## Factsheets and articles

- 4pp page Factsheet – Managing insect contaminants in processed leafy vegetables: A best practice guide.
- 4pp Factsheet – Blankets for vegetables; Using frost cloths to protect plants from weather
- Vegetables Australia, April 2016. A touch of frost – Using 'fleece' for winter frost protection.
- 4pp Factsheet – Floating row covers for vegetables (under production)
- 4pp Factsheet – Physical barriers for fruit fly management in vegetable crops (under production)
- 2pp Factsheet – Shady vegetables; costs and benefits of different shade materials for production of vegetables (under production)

All information and materials generated by the project will be promoted and made available through the ICP project website and the AHR website. This is an ongoing communication activity that will continue over the next 12 months.

# Outcomes

## Desktop review

Increased climate variability is a threat to the viability of vegetable farms around Australia. Issues include

- More unpredictable weather
- Higher average temperatures and increased frequency of heat-waves
- Increased risk of unseasonal frosts
- Storms and strong winds
- Changes in rainfall patterns.

Shading with nets or screens can reduce crop damage caused by high temperatures. Floating row covers can reduce or increase temperatures, depending on the type of material used. They can help protect crops from mild frosts, prevent sunburn and protect crops from insects.

The low cost protected cropping options with best technical potential and economic feasibility were:

1. Shading screens or shade houses
2. Floating crop covers
3. Wind breaks

## Permanent shade houses and nets

In these trials, netting had minimal effect on crop temperatures when used as a top-only over the crop. Adding sides restricts air movement, and can result in either an increase or decrease in temperature and RH, depending on the situation.

Although yield was unaffected by shading in these trials, it was noted that red shading resulted in darker leaf colour in baby spinach, while both white and red shade increased product shelf life. A hailstorm occurred in Stanthorpe during the trial period; although this did not affect the trial site itself, had it done so the netting system would have saved this crop while that in the field would have been unmarketable.

Capsicum plants grown in the retractable roof Cravo® house had at least double the growth, as well as large, dark leaves and a far healthier appearance than similar plants grown outside. In this case, capsicum crops grown in the open field nearby were destroyed by an extreme rainfall event, whereas those in the Cravo house were almost undamaged. Although initial yield assessments did not reflect the differences in plant size and health, had assessments been able to continue for the expected 9 month life of the crop, then large differences would likely have emerged.

## Floating row covers for summer production

It had been expected floating covers could provide some shade, reducing sunburn and maintaining more even soil moisture, as well as reducing insect contamination in the crop. However, in these trials a

number of issues were observed.

Sealing the nets proved an issue. While insect numbers were certainly reduced under the netting, insects were able to enter the crop through the open ends. The population of Rutherglen bugs was actually increased in one case, possibly due to these insects being protected from natural enemies by the netting. If prevention of insect contamination is a key objective, then nets must be securely fastened and left that way until harvest.

Weeds are often an issue in babyleaf crops, so thorough application of pre-emergent herbicides is essential. Where herbicide application was less than optimal, the warmer, moister environment under row covers increased weed seed germination and growth rates. It also made control more difficult. It is clear that effective weed control in beds prior to planting is essential if row covers are to be used.

One of the key benefits of netting materials on vegetable beds is that soil moisture is retained, reducing irrigation requirements. Although positive effects of floating covers on seed germination were observed in trials conducted during winter, these did not appear in the summer trial when conducted on a high organic matter soil with good irrigation coverage. This demonstrated that floating row covers are most likely to be of benefit if other crop production factors are suboptimal. That is, if crops are being grown in sandy soil and/or irrigation is infrequent or uneven.

None of these trials resulted in significant increases in yield or quality when leafy vegetables were grown under netting. While these materials can provide some protection from insects, wind and strong sunlight, none of these factors was a major issue during the trials, and in fact the negative impacts of nets were more significant. Use of netting materials during summer for leafy vegetable crops is therefore not supported by these results.

## Floating row covers for winter production

All of the spunbonded polypropylene 'fleece' materials tested increased germination growth and yield of lettuces grown over winter. The fleeces significantly increased both air temperature and soil temperature, and slightly raised humidity around the crop.

The fleece materials also reduced the number of insects within the crop, which could affect both crop damage and contamination of packed product. It appears that the best strategy may be to use these materials over winter until air temperatures increase to a regular daytime maximum of approximately 20°C. After this time, they may be removed to allow the crop to 'harden up' and possibly develop a richer colour.

There were few differences noted between the materials, with the exception of the 50g/$m^2$ fleece, which gave less positive results. It is notable that the lightest materials – which are also the cheapest – gave just as good a result (if not better) as heavier fabrics.

## Floating row covers for production of fruiting vegetables

Capsicum plants grown under VegeNet floating row cover had improved yield and better fruit quality. Floating row covers reduced the incidence of sunburn and could lower temperatures around the plants

during hot weather by providing some shading. The results were best when the row covers were installed when plants were still young, with less significant gains when the covers were installed late in development.

Plant growth was also enhanced under fleece type materials. Although plant maturity was not brought forward by as much as had been hoped, fruit maturity was somewhat advanced under these materials. Durability was an issue, especially under the windy conditions common in Bundaberg.

Although difficult to measure, perhaps one of the most striking effects of both the fleece and the VegeNet was improved plant growth. Plants that were protected from strong light and wind had larger leaves and appeared generally larger and healthier, without the curled leaf edges and sprawling habit of plants that were grown in the open. While this did not always directly result in improved yields, it seems likely that healthy plants will be less susceptible to disease and more resistant to pest attack. By reducing losses of moisture from the soil, plants protected using floating covers are likely to need less irrigation, while all of the covers tested proved effective at deterring one of the most significant pests of capsicums, Queensland fruit fly.

The same effects, however, were not observed for chilli plants protected by fleece or netting. No increases in either yield or quality were observed for cayenne or birds eye chillies grown with floating covers. The large size of the plants and more frequent harvests also made use of floating covers more problematic for chilli production. The major benefit of using floating covers for chilli plants was protection from fruit fly. This is not insignificant, as control of fruit fly is particularly problematic on chillies, which are an excellent host.

Although the same species as capsicum, there are clear differences in the response to floating covers by these two crops. This demonstrates that the effectiveness of these materials cannot be generalized; each crop, situation and climate needs to be considered independently.

# Evaluation and Discussion

While this project has involved a large number of trials of different materials, crops and environments, much remains unknown. For example, even the effects of a single product such as VegeNet varied between crops and environment. In some cases VegeNet reduced temperatures; in other situations temperatures increased; while under mild conditions there was often no change relative to the ambient air. Such variability may be due to factors such as sun strength, wind speed, soil temperature, relative humidity and the crop itself.

Moreover, although in some trials floating row covers increased yields, in other trials there was no effect or even negative impacts. If weeds were not controlled, or insects gained entry under the net, then the effects of floating covers could be distinctly negative.

The difference between capsicums and chillies is an example; both of these crops are *Capsicum annuum*, they vary only in terms of the cultivar and fruit size. Yet, the response of these crops to netting was distinctly different. The observed increases in yield and quality of capsicums did not translate to a similar effect on chillies. If anything, the effects on chillies were negative. The larger size of the chilli plants may be one factor, as these plants were partially constricted by the floating covers. However, other reasons for the different responses are unclear, and could be related to soil type or crop agronomy.

Floating row covers are most likely to be useful in somewhat marginal production environments. These include situations where temperatures are higher or lower than optimal, soil moisture is uneven, or pest pressure is difficult to manage by other means. So, floating row covers can increase germination of direct seeded lettuce in sandy soil with uneven watering, but are likely to provide little benefit in a high organic soil with a well managed irrigation system.

One of the best results gained during these trials involved the application of spun-bonded polypropylene fleece materials as floating covers during colder months. These materials were extremely effective at raising temperatures around the crop and in the soil. They could therefore allow production in areas that are otherwise unsuitable, or help bring a crop to market early in order to achieve premium prices (Figure 2). Perhaps most importantly, they can help protect the crop from extremes of weather, resulting in healthier, more resilient plants and good quality products.

It is interesting to note that the lightest – and cheapest – materials gave just as good a response as heavier weight fleece. This was not at the expense of durability; tearing and disintegration of the fleece was mainly a problem in the 50g/$m^2$ material, followed by those that weighed 30g/$m^2$. The lightest material presumably allows more air to flow through it, so by offering less wind resistance was least likely to tear.

Despite this, use of fleece in windy situations is likely to be problematic. Even the lightest fleece proved difficult to secure and tore easily in trial sites in Bundaberg.

**Figure 2. Difference in size of lettuces grown during winter in Werribee in the open (L) or under fleece material.**

Conversely, the heavy weight of fine weave nets is a significant impediment to their use. Even though these materials have potential to be an effective barrier against many insect pests, the difficulty of creating and maintaining a good seal around the edge can quickly render them ineffective. In addition, by increasing RH around plants, disease may be enhanced.

In general, the results suggest that floating covers that weigh more than 60 to 100g/$m^2$ can have negative, rather than positive, impacts on growth, depending on the crop in question. Suspending the net on a frame can overcome the issue of weight and restriction of the plants underneath. However, cloche hoops (see Ch.4 in Appendix 2 for details) were found to be too physically difficult, labour intensive and expensive to be a viable option for vegetables. Partial suspension using upended pots was also tested, but simply resulted in patchy growth and overall yield was not increased.

The floating row covers were very promising in alleviating the effects of extreme heat and cold in babyleaf spinach crops. There are more questions to be answered in relation to this crop group, and floating row covers should be evaluated more thoroughly on baby leaf crops and other leafy vegetables such as head lettuce and Asian greens.

The conflicting results with floating row covers on capsicums v's chillies also warrants further investigation. It is possible that regional differences in soils type and/or differences in crop management between the Qld capsicum trials and the NSW chilli trials could account for the different yield responses. We suggest the chilli trials are repeated in Bundaberg.

The impact on Queensland fruit fly control could be a major step forward in the management of that serious pest in capsicums and again requires more research.

Crop shading using more permanent structures has been widely reported to increase growth and yield of vegetable crops. However, the degree of shading must clearly be matched to light levels, particularly PAR (photosynthetically active radiation). If shading is too dark plants will become etiolated and weak and growth will be reduced. If too little shading is used then the cost of the structure will not be justified by improved productivity. Hail nets do clearly have some useful applications. Hail nets placed over crops such as hydroponic leafy Asian vegetables have produced excellent results in terms of yield, quality and shelf life. When the hail nets were brought to the ground these acted as a windbreak, further improving the growing environment and also reducing ingress of disease and insects (J Ekman, pers. com.). During this project hailstorms destroyed crops of spinach at Stanthorpe, damage from which the trial spinach crop under netting was protected.

The results showing the difference in leaf colour of plants grown under red netting could be of commercial significance; darker green colour could be regarded as an improvement in quality, while yield remained the same and shelf life was improved.

The results from the retractable roof Cravo® house were also very promising. The capsicums grown inside this structure were barely recognizable as the same species as the capsicums grown outside, even though the same variety was used (Figure 3). Plant health, size, vigour and commercially productive life were greatly increased using this system.

**Figure 3. Capsicum plants in Bundaberg grown in the open field (L) or inside a retractable roof greenhouse. Seedlings were planted at approximately the same date.**

While the Cravo® system is a relatively expensive 'low cost protected cropping' option, this relatively new technology is likely to be cost-effective for some higher value vegetable crops at least.

The trials of capsicums under retractable roof structures should be repeated as the plant growth improvement under these structures was not translated into higher yield, suggesting something like water or nutrient availability was limiting yield. This is quite possible, as the grower was new to the retractable roof structures, and may not have optimised the production system by the time of the trial, and these trials should be repeated.

In summary, the next steps should focus around a broader evaluation of floating row covers and retractable roof structures, both of which show considerable promise, but for which questions remain.

# Recommendations

There remains much to be understood about the effect of different shading materials and floating row covers on crop growth.

Findings and issues that are worthy of further exploration include:

- Red netting for production of salad greens; effects on quality, yield and shelf life of a range of vegetable crops.
- Criteria for use of fleece materials – optimising application time, responses of different crops, temperature limits for effective use (high and low).
- The degree to which floating covers can reduce irrigation requirements of different crops, and the extent to which savings in power and water can contribute to the cost of establishment.
- Floating covers suitable for Australian conditions; the materials tested during these trials were sourced directly or indirectly from overseas suppliers. If these were designed for use in Europe they may not have sufficient UV-C stabilizer to protect them from Australian conditions.
- Issues with re-use / recycling / disposal of floating row cover materials. None of the materials tested was biodegradable. The fleece materials are certainly single use as they tear easily. While woven netting materials may be re-usable over several seasons, it seems reasonable that they need to be cleaned between uses to avoid spreading weed seeds, plant pathogens or other pests around different areas of the farm.
- The impact of floating row covers and shade materials on pest management practices. As these materials change the environment around plants, they favour some pests while potentially eliminating others. For example, fruit flies are excluded, while aphids and weeds may thrive. Nets can interfere with cover sprays, or may make them unnecessary for some pests. Implementing low cost protected cropping systems therefore means changing pest management practices. For example, the release of beneficial insects under covers may help control pests. Growers wishing to use floating covers or shading therefore need to understand what other procedures they need to change.
- Investigate the economics of floating row covers in leafy vegetables and capsicums, perhaps using a case study approach.
- Focussed studies on the use of floating row covers to control Qld Fruit Fly – this is potentially a major breakthrough in the management of this important pest.
- Broader trials on the usefulness of floating row covers on leafy vegetable crops to include more babyleaf crops, head lettuce and baby Asian greens.
- Repeat the floating row cover chilli trials in Qld.
- Repeat the Cravo® retractable roof trials now that the grower is more experienced in capsicum crop agronomy under the system to provide a more realistic assessment of the yield and quality differences between retractable rooves and the open field.

# Intellectual Property/Commercialisation

No commercial IP generated

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- Mulyan Farms, Cowra
- N River Rd Farm, Carnarvon
- Redgold Farms, Robinvale
- Riviera Farms, Bairnsdale
- Tableland Hydroponics, Tolga
- Werombi Farm Produce, Silverdale
- Young Sang & Co, Bundaberg

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| | |
|---|---|
| Applied Horticultural Research | Jenny Ekman |
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| | Emma Winley |
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| IPMC | Andy Ryland |
| SG AgHort Consulting | Stuart Grigg |
| Bundaberg Fruit and Vegetable Growers | Bree Grima |

| | |
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| | Patrick Logue |
| Primary Principles | Jeremy Badgery-Parker |
| Total Horticultural Consulting | Brad Giggins |
| Landcare NT | Caroline Biggs |

# Appendices

**Appendix 1** – Review of low cost protected cropping for vegetables

**Appendix 2** – Full report on all trials including

- Reviews of different technologies
- Summary of netting materials tested, trials completed and results
- Materials and Methods for each trial
- All data, results and analyses
- Conclusions

**Appendix 3** – Selection of extension materials