FINAL REPORT

HRDC Project No.: VG 98050

“Development of a sustainable integrated permanent bed system for vegetable crop production including sub-surface irrigation extension”

Gordon Rogers, Stuart Little and Lionel Williams. Applied Horticultural Research.

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Dr. Gordon S. Rogers
Applied Horticultural Research
PO Box 552 Sutherland, NSW, 2232
Ph.: (02) 9527 0826
Fax: (02) 9544 3782
Email: Gordon@ahr.com.au

The purpose of this report is to finalise the Horticulture Australia Ltd. requirements for the project VG98050 **“Development of a sustainable integrated permanent bed system for vegetable crop production including sub-surface irrigation extension”**

The report is presented in two sections. The first section outlines the research conducted, presents results and conclusions from that research, and outlines the technology transfer undertaken by research staff to present the results of the research to vegetable growers and other research and industry bodies. The second section provides practical guidelines for the implementation of a permanent bed system for vegetable production. This section presents findings from the research and is complemented with photographs and diagrams to assist the reader in visualising the practical aspects of the system

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The final acknowledgement goes to Lionel Williams and the staff of Euri Gold Farms. Lionel Williams was instrumental in ensuring this project was conducted and without his enthusiastic support, many aspects of the research could not have been carried out. The many hours Lionel and other Euri Gold Farms staff have spent on the project is a tribute to Lionel’s vision and belief in the benefits of the permanent bed system.

TABLE OF CONTENTS

INDUSTRY SUMMARY 6
TECHNICAL SUMMARY 8
  Nature of the problem 8
  Methodology 8
  Major Research Findings and Industry Outcomes 9
  Recommendations to Industry, researchers and Horticulture Australia 9
  Contribution to new technology 10
  Future Work 10
Introduction 11
PART 1 – EXPERIMENT RESULTS 15
  Introduction 15
  Site descriptions 16
Area 17
University of Western Sydney – Hawkesbury, Richmond, NSW. 20
SECTION 1: Cover Crop Assessment – Dry Tropics 21
  Introduction 21
  Methods 21
  Results 23
  Discussion 31
  Cover Crop Assessments – Further Research 32
Summer 1998-99 32
Summer 1999-2000 32
Winter 2000 35
  Discussion of Further Research 35
SECTION 2: Cover Crop Assessment – Temperate Region 35
  Introduction 35
  Experiment 2.1: Winter 1999 35
  Results 36
  Experiment 2.2: Summer 1999/2000 36
Cover Crop Stage 36
Killing Cover Crops 37
Commercial Crop Stage 38
  Experiment 2.3: Summer 2000/01 39
Cover Crop Stage 39
Commercial Crop Stage 40
  Experiment 2.4: Winter/Spring 2001 41
Cover Crop Stage 41
Commercial Crop Stage 43
  Discussion 44
SECTION 3: Commercial Scale Production – Bowen 45
  Introduction 45
  1999/2000 Activities 45
Cover Crop Stage 45
Commercial Crop Stage 47
  Results 49
  Discussion 50
2000/2001 Activities 54
  Description of Activities 54
  Base Fertiliser Experiment 54

  Cover Crop Experiments......55
  Jaguar® Selective Herbicide Experiment......55
  Dual Salt Glyphosate Experiment......56
  Modified Planting Technique......57
SECTION 4: Changes in Soil Quality - Bowen......59
  Introduction......59
  Results......60
Soil Organic Carbon......60
Worm Populations......60
Soil Aggregate Stability......61
Soil Bulk Density......62
Nematode Assessment......63
Soil Microbial Assessment......64
Interpretation......66
Soil Temperature......66
  Discussion......67
SECTION 5: Allelopathy and Nutrient Drawdown Experiments......68
  Introduction......68
  Methods......68
Nutrient Drawdown Experiment......68
Allelopathy Experiment......68
  Results......69
Nutrient Drawdown Experiment......69
Allelopathy Experiment......70
  Discussion......72
SECTION 6: Crop Evaluation Experiments......73
  Introduction......73
  Methods......73
  Results......74
  Discussion......76
SECTION 7: Irrigation Experiment – Bottom Up Irrigation......77
  Introduction......77
  Methods - Experiment 1, 1999......78
  Results - Experiment 1, 1999......78
  Methods - Experiment 2, 2000......80
  Results - Experiment 2, 2000......80
  Discussion......82
SECTION 8: Herbicide Experiments - Bowen......83
  Introduction......83
  Herbicide Experiment – Methods......83
  Herbicide Experiment – Results......83
  Herbicide Evaluation......84
  Herbicide Evaluation – Results 1999......84
  Herbicide Evaluation – Results 2000......85
  Herbicide Evaluation – Results 2001......86
  Discussion......86
SECTION 9: Technology Transfer......87
  1. Sustainable Vegetable Production Field Day, Euri Gold Farms, Bowen, 10th October 2000......87
  2. Grower Meetings......88

(i) Growing For Profit, Gympie, November 15th 2000 ... 88
(ii) Gympie Growing For Profit 2 and Queensland Extension, 4th September to 14th September 2001 ... 89
(iii) Sweet Corn IPM Meeting – Cowra, 16th October 2001 ... 90
3. Horticultural Expos ... 91
(i) North Queensland Field Days - Ayr Research Station, 10th-11th September 1999. 91
(ii) “Expo 16” – Gatton Research Station, 17-18th May 2000 ... 91
(iii) “Sydney Basin Vegetable Expo” University of Western Sydney – Hawkesbury, 11th & 12th May 2001 ... 91
4. Information Mail Outs ... 92
5. US No-Till Study Tour ... 92
USDA Research into No-Till Vegetables ... 93
6. Industry Development Officers ... 94
7. Publications ... 94
Articles in Good Fruit and Vegetables ... 94
Articles in Newsletters and Grower Magazines ... 95
Other Publications and Presentations ... 96
International Communications ... 96
References ... 97

INDUSTRY SUMMARY

The project was initiated in response to increasing concerns over the use and disposal of agricultural plastic and declining soil structure in vegetable production systems through cultivation and loss of soil organic matter. Current tillage practices in vegetable production break up the natural soil aggregates and cause a decline in the levels of soil organic matter that binds the soil particles together. This loss of organic matter over time leads to a decline in soil structure and problems such as soil erosion, surface crusting, the formation of hardpans, and poor infiltration.

The bed system developed through this research uses permanent beds that are sown with a cover crop. The cover crop is then killed when sufficient biomass has been produced and the residues are left on the bed surface. The act of leaving residues to break down on the soil surface increases organic matter within the soil leading to improvements in soil structure over time. Commercial crops are then transplanted through the residues, which form an organic mulch that suppresses weeds and retains moisture within the soil.

The retention of an organic mulch on the soil surface and a reduction in cultivation results in an increase in active organic matter within the soil. This increase in organic matter promotes improvements in soil physical and biological properties that can in turn be of benefit to crop productivity. Worm populations have increased from zero counts per cubic meter of topsoil under conventional practices to a maximum of 8000 per m^3 in the permanent bed system.

The stability of soil aggregates has improved significantly with aggregates in the permanent bed system rating 3 out of 4 for stability compared to a rating of 1 for the soil aggregates sampled from the conventional production areas. This improvement in soil aggregation and stability has resulted in a more friable, less compacted soil as shown by the lower soil bulk density relative to conventional cultivation and plastic production areas.

A comparison of production in trellised tomatoes showed that conventional tomato production produced higher yields in the first four picks than production on the permanent beds, whilst the crops on permanent beds had a higher yield after the first four picks. Total yields are similar between the two systems, but are delayed where organic mulch is used instead of black plastic.

Other crops have been grown in experiment plots using the permanent bed system, all of which were grown to harvest without any growth suppression. Crops grown include Capsicum, Eggfruit, Rockmelon, Pumpkin, Honeydew, Broccoli and ground tomatoes. There can be an increase in damping off diseases in seedlings transplanted through mulch, and this seems to be more on an issue when planting into fresh mulch residues.

Improvements in soil structure mean more air and moisture can be held within the soil; crop roots can move through the soil and establish faster; high levels of rainfall are rapidly drained away allowing earlier vehicular access to production areas; and soils are less prone to erosion in all conditions. A healthy well-structured soil is vital to the continued productivity of horticultural systems.

TECHNICAL SUMMARY

Nature of the problem

The project was initiated in response to increasing concerns over the use and disposal of agricultural plastic and declining soil structure in vegetable production systems through cultivation and loss of soil organic matter.

Current tillage practices in vegetable production break up the natural soil aggregates and cause a decline in the levels of soil organic matter that binds the soil particles together.

This loss of organic matter over time leads to a decline in soil structure and problems such as soil erosion, surface crusting, formation of hardpans, and poor infiltration.

There is considerable research on various components of a sustainable vegetable production system, such as: planting vegetables into in-situ grown mulches instead of plastic mulch; permanent beds (controlled traffic); no-till techniques; biofumigation.

Apart from Abdul-Baki and Teasdale (USDA) there have been no reported attempts to combine these components into a practical, on-farm production system.

The objective of this project was to combine these techniques into a system and test it on a commercial vegetable farm inn Australia.

Methodology

The techniques selected were:

1. Install sub-surface trickle irrigation
2. Drill fertilizer pre-plant
3. Growing cover crops in place, killing them and then planting vegetables directly into the residue.
4. Transplanting vegetable crops into the mulch residue
5. Adapt existing growing techniques for the new system
6. Replant cover crop and repeat cycle

This was tested both on a commercial vegetable farm in Bowen, North Queensland, and on a experiment area of the University of Western Sydney at Richmond, NSW.

Major Research Findings and Industry Outcomes

The major findings were:

- It is possible to grow vegetable crops commercially without cultivation, by planting through mulch residues using trickle irrigation on permanent beds.

- The soil health improves over time due to organic mulch covering the soil continuously. In addition, soil bulk density decreases over time and is lower than frequently cultivated soil despite the lack of cultivation.

- There can be allelopathic effects of the cover crop on the subsequent vegetable crop however these are minor except for sorghum which strongly inhibits the growth of subsequent crops and capsicums which are highly sensitive to allelopathic effects.

- It is possible to transplant vegetable seedlings into cover crop resides within several days of killing the crop.

- Weed control is a major issue. It is important to control weeds in the cover crop, and prevent weed seed production. This way, weed seed populations decline and after about 5 years are significantly reduced.

- Killing the cover crop prior to planting the vegetable crop is crucial. Data is presented in killing Centro with a range of herbicides. Winter cereals and millet can be killed effectively with glyphosate and rolling. Rolling alone can be effective on cereals provided the plants are in the early seed set stage. Rolling in addition to herbicide on cereals provides an excellent mat and is more reliable.

- Centrosema pubescens was the most effective cover crop for summer in the tropics. Cereals (oats, rye) were effective in winter. For temperature regions, oats, barley and wheat were most effective in winter and millet was best in summer.

- Improvements in soil structure mean more air and moisture can be held within the soil; crop roots can move through the soil and establish faster; high levels of rainfall are rapidly drained away allowing earlier vehicular access to production areas; and soils are less prone to erosion in all conditions. A healthy well-structured soil is vital to the continued productivity of horticultural systems.

Recommendations to Industry, researchers and Horticulture Australia

Vegetable crops including Capsicum, Eggfruit, Rockmelon, Pumpkin, Honeydew, Broccoli and ground tomatoes can be grown effectively using in-situ cover crops and

Contribution to new technology

1. Cover crop species have been evaluated in two Australian growing regions (Dry Tropics, North Queensland) and Richmond, NSW.

2. Compatibility with Capsicum, Eggfruit, Rockmelon, Pumpkin, Honeydew, Broccoli, trellis and ground-grown tomatoes has been evaluated.

3. The use of buried trickle irrigation in permanent beds using in-situ cover crops has been evaluated.

4. The effects of in-situ cover crops and permanent beds on soil health has been evaluated.

Future Work

1. Cover crops have only been tested in two climatic regions, and over two soil types. There is a great deal of interest in implementing the system more widely across the country, and information on suitability and timings of various potential cover crop species is urgently needed.

2. The system needs to be adapted to perennial cropping systems such as fruit trees and vines.

3. Increased frequency of damping off in crops transplanted through mulch residues compared to bare soil or plastic mulch needs to be investigated.

4. Techniques need to be developed for the successful direct seeding of crops such as melons, carrots, onions and beetroot through mulch residues. Planting of seed potatoes through mulch resides should also be investigated.

Introduction

The project was aimed at overcoming fundamental problems associated with the current practice of annually installing and removing trickle irrigation and plastic mulch in vegetable production systems. A broad range of vegetable crops are grown using beds which are re-formed each season, in many cases using plastic mulch to control weeds and maintain soil moisture, and drip irrigation to supply water and some nutrients.

While these practices have permitted the production of high quality crops, it has caused a rapid decline in soil physical properties, and a reduction in crop yields. The yield decline appears to be related to poor soil physical conditions associated with declining organic matter levels combined with an increase in the incidence of soil-borne diseases. Current practices limit further sophistication of the production system and in presents problems with sustainability in the long term.

Specifically, the problems associated with the trickle/plastic mulch system are:

1. The practice of long fallows (2 - 3 years) or rotations with cover crops or other crops to combat the decline in yields and quality. This is costly, results in more land clearing that would otherwise be necessary, and does not result in a sustainable system.

2. Soil organic matter (OM) levels decline under this system, especially in warmer areas where low OM inputs, high levels of available nutrients and water combined with high temperature mean that soil organic matter levels in such systems in the tropics are typically less than 0.5 %. Such low soil OM levels lead to lower populations of soil organism levels, and a degradation of stable soil structure. Cultivation frequency is then increased in an attempt to alleviate structural problems which further increases the rate of organic matter loss..

3. Current practices are costly and wasteful in terms of the energy required to lay, produce and remove the plastic mulch and trickle irrigation tube. These materials then present a problem for disposal. In many cases, this plastic is simply "ploughed in" resulting in stable residues, which represents an environmental pollutant.

4. Soil compaction occurs due to tractors driving over soil which may in the following year become part of a bed: i.e., beds don’t go back in the same place each year. This encourages further cultivation which perpetuates the problem.

5. Variations in crop growth and quality occur due to residues of previously banded fertilisers and soil amendments which remain in the soil. This results in a lack of uniformity in subsequent crops because there are different levels of nutrient availability to plants across a block.

6. Soil amendments (e.g., lime and gypsum) and fertilisers which are broadcast are wasted because the portion which falls between rows is not used by foraging roots and hence remains after the crop is harvested. This contributes to the problem outlined in point 5 of this section and also represents a pollution hazard, since these fertilisers can be leached or otherwise transported into water systems.

7. The installation of semi-permanent irrigation systems is precluded due beds being placed in different positions each year.

The use of permanent beds and minimum tillage immediately counters the problems outlined in points 5, 6 and 7. By ensuring beds remain in the same location each year, fertilisers, soil amendments, and location of irrigation lines are focussed within the root zone of future crops. As fertiliser and soil amendments are not broadcast across the entire production area in the permanent bed system, nutrients are not wasted on non-production areas and hence nutrient leaching and runoff potential is minimised.

By minimising cultivation, the use of permanent beds encourages improvements in soil structure such as increasing infiltration and aggregate stability and therefore reducing erosion and runoff. However without increases in soil organic matter a permanent bed system cannot be sustained in the long term. Organic matter in the soil contributes to improved soil structure, infiltration, increased water holding capacity, and higher cation exchange capacity. Therefore the use of organic mulches in combination with minimum tillage can contribute substantially to the sustainability of vegetable production systems.

Researchers in the United States have led current research into the use of in-situ organic mulches, whilst research in Australia using similar practices has focussed on the temperate regions of NSW and Victoria. Research into minimum tillage using organic mulches has found improvements in soil compaction levels, moisture retention, lower soil temperatures, and equal levels of weed suppression. Yields of a range of vegetable crops were typically equivalent to or higher in most experiments, however some researchers found that crops grown in mulch produced lower yields than conventional production.

Adem and Tisdall (1984) found improvements in soil aggregate stability of 35% where untilled soil under a mulch of ryegrass was compared to an untilled control, whilst Stirzaker and White (1995) noted a significant improvement in soil compaction levels under sub-clover mulch. Improved soil moisture levels relative to cultivated control plots were recorded by Schonbeck et al. (1993), Creamer et al. (1996), and Saiju et al. (2000).

Lower soil temperatures under organic mulch relative to bare soil and plastic mulches were noted by Stirzaker et al. (1989), Schonbeck et al. (1993), Stirzaker and White (1995), Creamer et al. (1996) and Borowry and Jelonkiewicz (2000). Teasdale and Abdul-Baki (1995) quantified the temperature difference under organic mulch relative to black polyethylene to be 5.7°C at 5cm depth and 3.4°C at15cm. This temperature difference resulted in tomato plants under black plastic receiving more hours at optimum soil temperature, resulting in higher yield.

Phytotoxicity was observed by Stirzaker and Bunn (1996) in a glasshouse experiment where seedlings of tomato, broccoli and lettuce were sequentially planted into soil taken from under clover and millet in-situ mulches, imported lucerne mulch, and control plots. The results showed that phytotoxicity by clover cover crops lasted 6 weeks, millet phytotoxicity lasted much longer and was more severe, whilst no phytotoxicity was observed in control or under lucerne tops.

Yield results from published research show that the majority of crops grown under minimum tillage with organic mulches produced equivalent or greater yields than conventional cultivation or bare soil controls. A summary of research is outlined below:

- De Frank and Putnum (1978) found that higher yields of Snap Beans were produced when grown in a mulch of mown sorghum relative to bare soil treatments.
- Morse and Seward (1986) observed greater or equivalent yields in broccoli and cabbage under vetch, pea or rye mulches relative to conventional production.
- Stirzaker et al. (1989) showed greater yield of lettuce when comparing no-till with sub-clover mulch to no-till without mulch.
- Morse (1993) found that cabbage under wheat and rye mulch yielded higher than control in limited water scenarios, and equivalent to control under normal conditions.
- Abdul-Baki and Teasdale (1993) showed higher yields of tomato under vetch and sub-clover mulches relative to plastic, paper or bare soil. However fruit maturity was delayed under the organic mulches by 10 days relative to the plastic mulch treatment.
- Schonbeck et al. (1993) showed that vetch and vetch in combination with rye mulches produced higher broccoli and cabbage yield than rye alone or bare soil treatments.
- Stirzaker et al. (1993) showed higher lettuce yield under sub-clover mulch in a highly compacted soil, and equivalent yields in a less compacted soil.
- Abdul-Baki et al. (1996) showed higher yields in tomatoes in 2 out of 3 years under hairy vetch, crimson clover, and rye in combination with hairy vetch relative to black plastic. Nitrogen applications under the organic mulches were also cut to 50% of the black plastic application.
- Smeda and Weller (1996) found that yield of tomato under a rye mulch was equal to conventional tillage only when the mulch provided weed suppression for the first 4-5 weeks after transplant.
- Abdul-Baki et al. (1997) produced equivalent yields of broccoli under soyabean, millet and combination mulches relative to conventional tillage.
- Bottenberg et al (1999) and Roberts et al. (1999) observed lower yields of snap bean and cabbage respectively in rye mulch relative to conventional tillage.
- Saiju et al. (2000) found improved nitrogen availability and root proliferation under organic mulches.

In a review of no-till vegetable production research, Morse (1999) found that the the success of no-till vegetable production was dependant upon four key aspects:

- The production of dense, uniformly distributed cover crops,
- Skilful management of the cover crop before vegetable establishment,
- Establishment of the vegetable crop with minimal soil disturbance, and
- Adoption of year round weed control.

In addition to these points, the research outlined above indicates that the use of leguminous cover crops, or careful management of Nitrogen in grass or cereal cover crops is also fundamental to higher yields in no-till vegetable crops.

PART 1 – EXPERIMENT RESULTS

Introduction

This section outlines results from the small plot replicated experiments and larger-scale commercial trials conducted as part of this research project. Initial experiments focussed on screening a range of potential cover crops for both summer and winter cropping systems. Following these experiments, successful cover crops were planted in larger scale experiments used to develop the system as a whole, whilst cover crop screening experiments continued in an effort to find other potential cover crops for use in the permanent bed system.

Allelopathy and herbicide experiments were undertaken in an attempt to answer specific issues identified in earlier larger-scale experiments, whilst the crop evaluation experiment examined the performance of other vegetable crops under the permanent bed system.

Throughout both the small and commercial experiments a major focus of the project was the changes in soil physical, chemical and biological properties under the minimum tillage regime. Samples of soil were assessed for organic carbon, soil bulk density, aggregate stability and soil microbial activity and worm populations.

Some outcomes were derived from unreplicated trials yet this data has been important in developing a successful management system. These observations have been included within the details of the commercial experiments and are included in the practical details in Part 2 of this report.

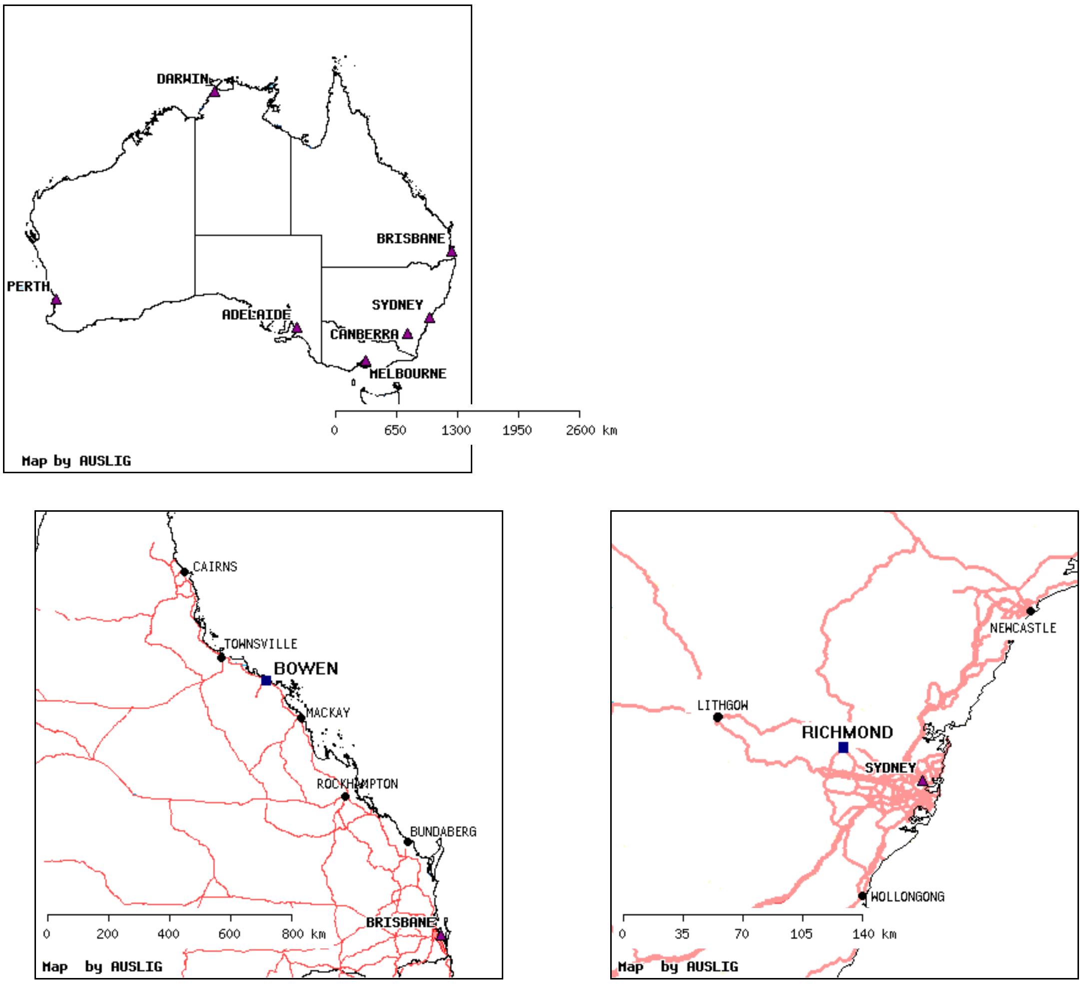
Table I.1: Summary of Experiments Conducted

Experiment	Experiment Site	Year(s)
Cover Crop Assessment – Dry Tropics	H23 AHR TA AHR TA	1998-9 2000 2001
Cover Crop Assessment – Temperate	UWSH	1999-2001
Commercial Crop Experiments	H23, H2, H1	2000-2001
Soil Health Changes	Euri Gold Farms	1997-2001
Allelopathy Experiment	H23	1999
Crop Evaluation Experiments – Dry Tropics	AHR TA	2000
Crop Evaluation Experiment - Temperate	UWSH	2000-2001
Irrigation Experiment – Bottom Up Irrigation	AHR TA	1999-2000
Irrigation Experiment – Nelson Irrigation	H2	2000
Herbicide Experiment	AHR TA	2000

Site descriptions

Experiments were conducted in two main locations. Commercial experiments and large-scale cover crop experiments were conducted of property leased by Euri Gold Farms managed by Lionel and Dale Williams in Bowen, North Queensland. Smaller experiments to evaluate winter cover crops were conducted on a leased site on the University of Western Sydney –Hawkesbury, Richmond campus. Location of Bowen, Qld. and Richmond, NSW are shown in Figure S.1. Temperature and Rainfall data for Bowen and Richmond is summarised in Figure S.2 and S.3.

Figure S.1: Location Maps of Bowen, Qld. and Richmond, NSW. (Adapted from AUSLIG, 2001)



Euri Gold Farms, Bowen, Qld.

Euri Gold Farms is located approximately 15km North and 15 km West of the township of Bowen (20°00’S Lat. 148°14’E Long.) Experiments were conducted on 5 sites throughout the property. Experiments conducted at each site are listed in Table S.1, site characteristics are summarised in Table S.2 and soil and water testing results shown in Table S.3.

Table S.1: Location of Experiments Conducted in Bowen, Qld.

Experiment Site	Experiments Conducted
Hydrant 23 Left	Cover crop experiment (98), Allelopathy Experiment (99), Commercial Production (2000 & 2001)
Hydrant 2 Left and Right	Commercial Production (1998-2001) Nelson Irrigation tube installed (2000)
Hydrant 1 Left and Right	Commercial production (2000), EM experiment site (2001)
AHR Experiment Area	Irrigation Experiment (98-2001), cover crop experiments ('00 & '01), Vegetable Crop Experiments (2000), Herbicide Experiment (2000)

Table S.2: Site Characteristics – Bowen, Qld.

	H23 L	H2 L&R	H1 L&R	AHR T.A.
Area	1.2 ha	L: 1.16 ha R: 1.06 ha	L: 1.59 ha R: 1.2 ha	0.2 ha
Rows	39	L: 29 R: 24	L: 54 R: 34	10
Average Row Length	170m	L: 225m R: 245m	L: 165m R: 196m	5 x 115m 5 x 90m
Slope	<0.1%	2%	2%	<0.1%

Table S.3: Soil and Water Test Results – Bowen, Qld.

Soil Test Results	
Nutrient	**Level**
pH (in water)	6.5
Conductivity	0.17 dS/m
Nitrate	30 mg/kg
Phosphorus(Col.)	45 mg/kg
Sulphur (KCL)	11 mg/kg
Copper	1.7 mg/kg
Zinc	0.9 mg/kg
Manganese	42 mg/kg
Iron	50 mg/kg
Boron	0.3 mg/kg
Organic matter	1.5 %
Chloride	140 mg/kg
Sodium	60 mg/kg
Potassium	80 mg/kg
Calcium	850 mg/kg
Magnesium	270 mg/kg

Water Test Results	
Nutrient	**Level**
pH	7.2
Conductivity	1630µS/cm
Calcium	100 mg/L
Magnesium	93 mg/L
Sodium	100 mg/L
Chloride	270 mg/L
Phosphorus	<1 mg/L
Potassium	4 mg/L
Sulphur	7 mg/L
Aluminium	<0.1 mg/L
Zinc	0.01 mg/L
Iron	0.01 mg/L
Copper	0.01 mg/L
Manganese	<0.01 mg/L
Boron	0.05 mg/L
Molybdenum	<0.05 mg/L
Total Dissolved Ions	1040 mg/L
Total Hardness	633 mg$CaCO_3$/L
S.A.R.	1.7

The AHR experiment area was set up to run the irrigation experiment as shown in Section 7: Irrigation Experiment (page 77), all other experiment areas had 2 tapes per bed of Netafim trickle tape installed 30cm apart at a depth of 10cm. Nelson irrigation tape "Pathfinder" was installed in Hydrant 2 in the summer of 2000 using 2 tubes per bed 20cm apart at a depth of 15cm.

Figure S.2: Climate Graph for Bowen, Qld. (Adapted from Bureau of Meteorology (2001).

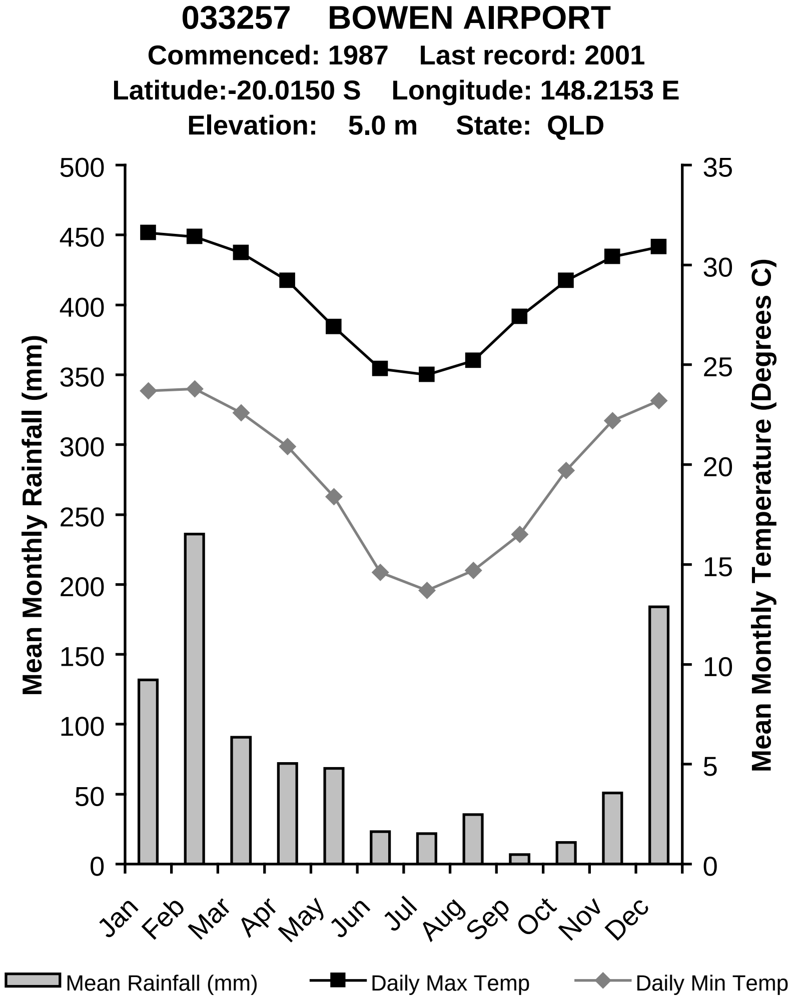
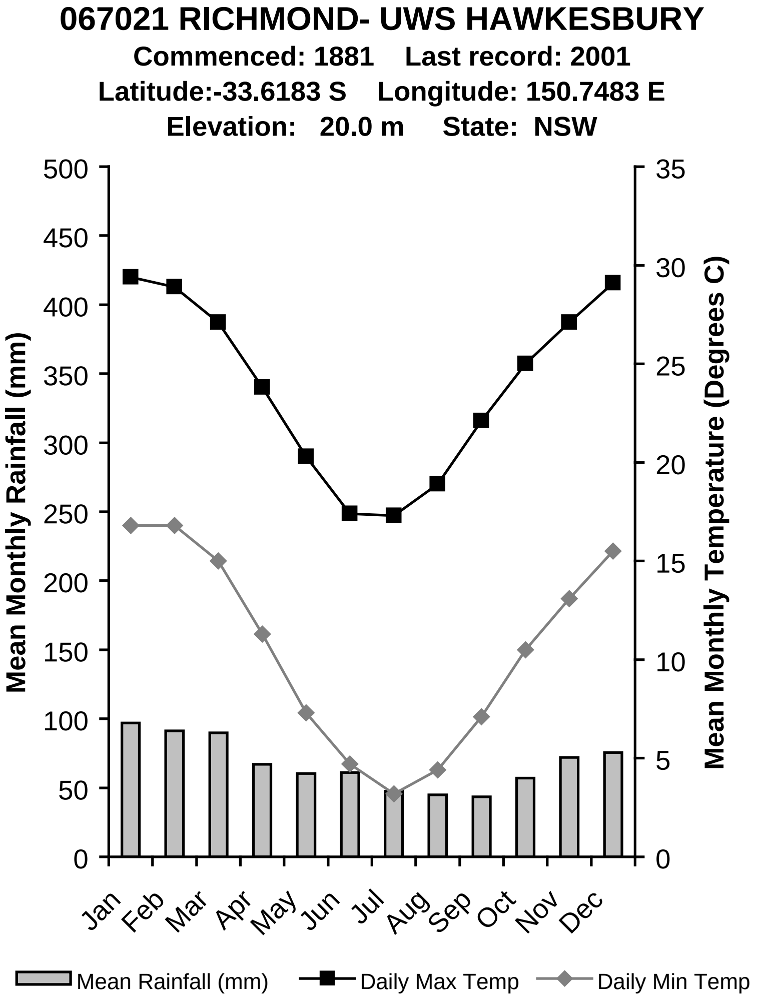


Figure S.3: Climate Graph for Richmond, NSW. (Adapted from Bureau of Meteorology (2001).



University of Western Sydney – Hawkesbury, Richmond, NSW.

The experimental site at the University of Western Sydney – Hawkesbury (UWSH) at Richmond, NSW (33°35’S Lat. 150°46’ Long.) was used to conduct small-scale experiments in a temperate climate where winter cover crops and the performance of spring/summer commercial crops could be evaluated. Initial experiments were conducted over an area with 6 rows 25m long and 4 rows 45m long. Later experiments were conducted over a smaller area consisting of 5 rows at 2m spacing by 25m-row length. Soil test results are shown in Table S.4. Experiments conducted are described in detail in Section 2: Cover Crop Assessment – Temperate (page 35).

Table S.4: Soil nutrient levels at UWSH experiment site.

Nutrient		**Level**
pH (in water)		**5.5**
Nitrate	mg/kg	**38**
Phosphorus(Col.)	mg/kg	**35**
Sulphur	mg/kg	**20.5**
Copper	mg/kg	**2.2**
Zinc	mg/kg	**1.6**
Manganese	mg/kg	**25**
Iron	mg/kg	**166**
Boron	mg/kg	**0.8**
Organic matter	%	**2.1**
Conductivity	dS/m	**0.10**
Chloride	mg/kg	**18**

Cations	**mg/kg**	**meq/100g**
Sodium	**16**	**0.1**
Potassium	**250**	**0.6**
Calcium	**1500**	**7.5**
Magnesium	**170**	**1.4**
Aluminium	**15**	**0.2**
Cation Exchange	meq/100g	**9.8**
Ca/Mg Ratio		**5.3**

SECTION 1: Cover Crop Assessment – Dry Tropics

Introduction

The objective of this experiment was to screen potential cover crops for suitability in the minimum tillage system. Cover crops suited for the system need high biomass, provide good weed suppression, and form long-lasting mulch. Initial experiments focused on biofumigant plants, and plants used successfully in similar experiments in other areas. Experiments conducted as the system developed investigated plants that could produce stable mulches and provide fast ground cover and hence weed suppression.

Methods

The H23 experiment area was broadcast sown with a range of potential cover crops at the sowing rates outlined in Table 1.1.

The experiment design was a split plot where the cultivars of cover crop were planted along the rows and replication was along the row. This was a compromise between rigour and practicality as issues relating to crop management and machinery could be investigated by using realistic row lengths. The long rows however precluded replication of full rows because of limitations of area and the number of varieties of cover crop being investigated.

Cover crop performance was evaluated by visual assessment along the following characteristics:

- establishment rating,
- growth performance, and
- weed suppression ratings.

Biomass measurements were also determined by cutting 4 replicates of a $0.3m^2$ quadrat, drying the biomass at 70°C and weighing the dried biomass. Biomass is expressed in $kgDM.ha^{-1}$.

Soil samples were taken prior to establishment of the experiment, during growth of cover crops and after cover crops were killed. Soil samples were analysed for pH, EC, organic carbon, soluble and exchangeable cations, micro-nutrients, aggregate stability and bulk density. Soil samples were composites of 15 sub-samples, replicated twice.

Table 1.1: Cover crop details and sowing rates.

Cover crop	Scientific Name	Plant Type	Sowing Rate
KRC 4063	*Brassica napus*	Biofumigant	30 kg.ha^{-1}
KRC 2919	*Brassica napus*	Biofumigant	30 kg.ha^{-1}
KRC 3925	*Brassica oleraceae*	Biofumigant	30 kg.ha^{-1}
Rangi rape	*Brassica napus*	Biofumigant	30 kg.ha^{-1}
Yellow mustard	*Sinapis alba*	Biofumigant	30 kg.ha^{-1}
KRC 2809	*Brassica napus*	Biofumigant	30 kg.ha^{-1}
KRC 4851	*Brassica napus*	Biofumigant	30 kg.ha^{-1}
KRC 837	*Brassica napus*	Biofumigant	30 kg.ha^{-1}
KRC 4880	*Brassica campestris*	Biofumigant	30 kg.ha^{-1}
KRC 2863	*Brassica campestris*	Biofumigant	30 kg.ha^{-1}
KRC 2936	*Brassica oleraceae*	Biofumigant	30 kg.ha^{-1}
KRC 912	*Brassica oleraceae*	Biofumigant	30 kg.ha^{-1}
Villosa mix		Legume	30 kg.ha^{-1}
Hunter lucerne	*Medicago sativa*	Legume	30 kg.ha^{-1}
Verano stylo		Legume	30 kg.ha^{-1}
Japanese millet	*Echinochloa esculenta*	C4 Tropical Grass	30 kg.ha^{-1}
Cavalcade centrosa	*Centrosema pubescens*	Legume	25 kg.ha^{-1}
Indian Bluegrass – Hatch	*Bothriochloa pertusa*	Tropical grass	15 kg.ha^{-1}
Indian Bluegrass – Keppel	*Bothriochloa pertusa*	Tropical grass	15 kg/ha^{-1}
Weedcheck	*Brassica raphanus*	Legume	8kg.ha^{-1}
Nemfix	*Brassica juncea*	Brassica	20kg.ha^{-1}
Forage sorghum	*Sorghum bicolor*	C4 Tropical Grass	
Rangi rape & Japanese millet	*Brassica napus*	C4 Tropical Grass	30 kg.ha^{-1}
Hunter lucerne & Villosa mix	*Medicago sativa*	Legumes	30 kg.ha^{-1}
SCO 8002	*Trifolium alexandrinum*	Legume - clover	8kg.ha^{-1}
SCO 8003	*Trifolium resupinatum*	Legume - clover	8kg.ha^{-1}
SCO 8004	*Trifolium resupinatum*	Legume - clover	8kg.ha^{-1}
SCO 8005	*Trifolium resupinatum*	Legume - clover	8kg.ha^{-1}
SCO 8006	*Trifolium resupinatum*	Legume - clover	10kg.ha^{-1}
Bare soil control			
Plastic mulch control			

Note: The KRC lines were supplied by Wrightsons Seeds New Zealand. The SCO lines were supplied by SeedCo - South Australia.

Cover crops that did not form suitable mulch were sprayed with glyphosate then covered with sorghum mulch to prevent further weed growth.

Cover crops with potential as in situ mulches were sprayed with a mixture of glyphosate and diuron to kill them. The lack of mulch produced by the biofumigant plants (see Results) was compensated for by importing sorghum straw and covering the beds where the brassicas were grown. Fusarium oxysporum (Race III) susceptible egg tomatoes were planted into the mulch plots to assess to give some indication of activity of Biofumigant plants against Fusarium. Crop nutrition was managed by monitoring leaf nutrient levels in the growing crop and injecting nutrients through the trickle irrigation system.

Results

Establishment and plant vigour were best in the Brassica cover crops with most forage brassicas (especially *Brassica napus*) varieties establishing rapidly and providing a dense ground cover. Brassica oleraceae varieties established rapidly but also flowered early, reducing the plants ability to produce further biomass. The best non-Brassica cover crops were the tropical grasses sorghum and the two Indian Bluegrass varieties. The legume species did not establish well and could not out-compete emerging weeds, except the tropical legume *Centrosema cavalcade* which showed excellent growth despite slow establishment. Weedcheck and Nemfix brassicas and Japanese millet all set seed rapidly and were unsuitable as summer cover crops. Further details of cover crop performance are outlined in Table 1.2.

Table 1.2: Cover crop establishment and growth performance.

Cover crop	Establishment	Growth Performance
KRC 4063	Good	Good cover
KRC 2919	Good	Good cover
KRC 3925	Poor	Poor
Rangi rape	Good	Good cover
Yellow mustard	Good	Bolted to seed
KRC 2809	Good	Good cover
KRC 4851	Good	Good cover
KRC 837	Good	Good cover
KRC 4880	Good	Good cover
KRC 2863	Moderate	Moderate cover
KRC 2936	Poor	Poor
KRC 912	Poor	Poor
Villosa mix	Poor	Poor
Hunter lucerne	Poor	Poor
Verano stylo	Poor	Poor
Japanese millet	Good	Seeded early
Cavalcade centrosa	Slow	Good cover
Indian Bluegrass - Hatch	Good	Good cover
Indian Bluegrass - Keppel	Good	Good cover
Weedcheck	Poor	Poor
Nemfix	Good	Bolted to seed
Forage sorghum	Good	Good cover
Rangi rape + Japanese millet	Good	Millet set seed early
Hunter lucerne + Villosa mix	Poor	Poor
SCO 8002	Poor	Poor
SCO 8003	Poor	Poor
SCO 8004	Poor	Poor
SCO 8005	Poor	Poor
SCO 8006	Poor	Poor
Bare soil control		
Plastic mulch control		

All cover crops that established well and did not seed early produced sufficient cover and weed suppression during growth. The Indian bluegrass varieties showed the highest level of weed suppression with Brassica napus variety 4851 and Centro cavalcade also providing excellent levels of suppression (see Figure 1.1).

Figure 1.1: Weed suppression ratings for cover crop species.

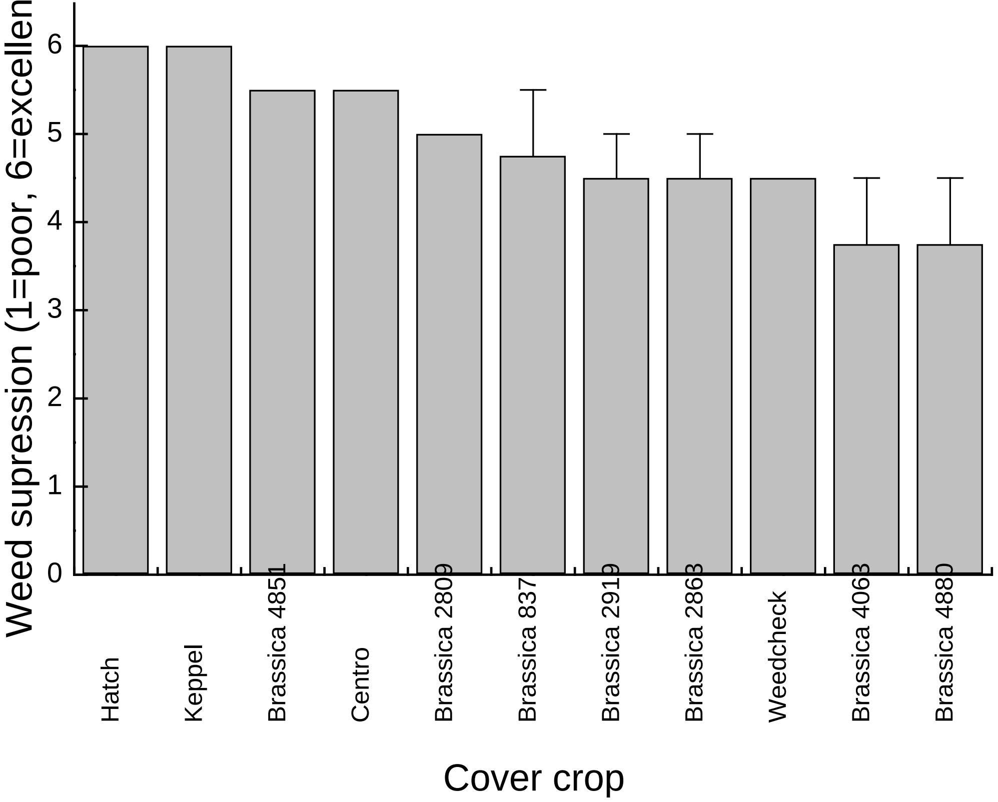
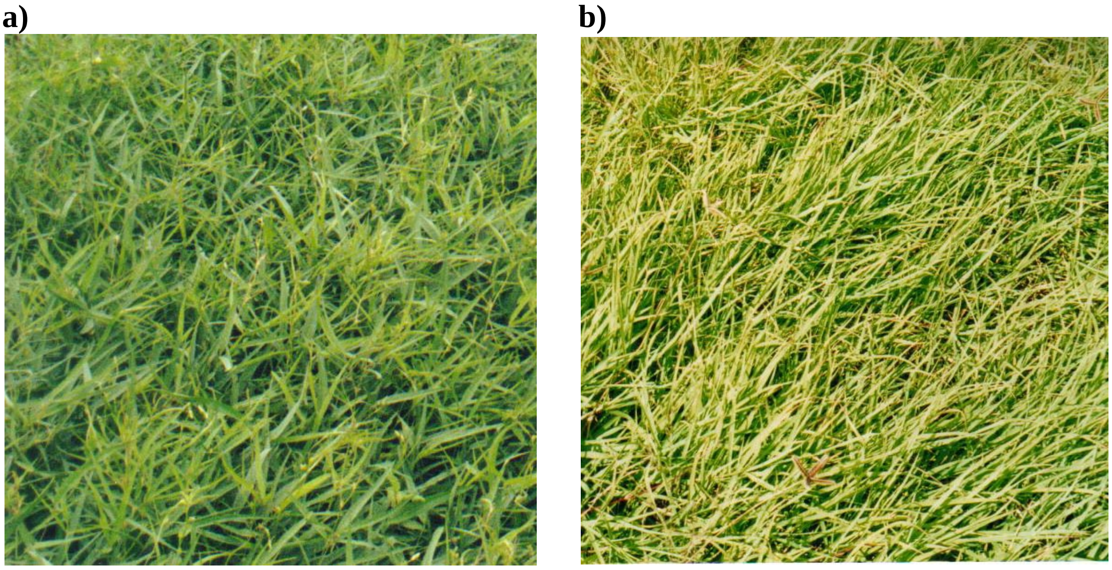
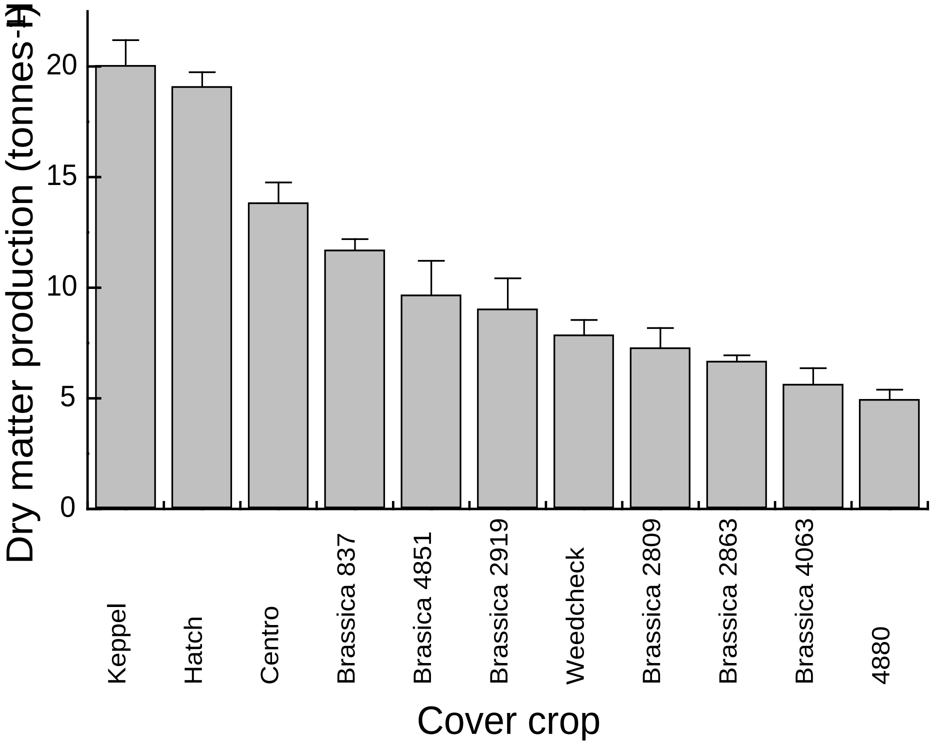


Figure 1.2: Cover produced by a)Centro Cavalcade and b)Indian Bluegrass "Keppel"



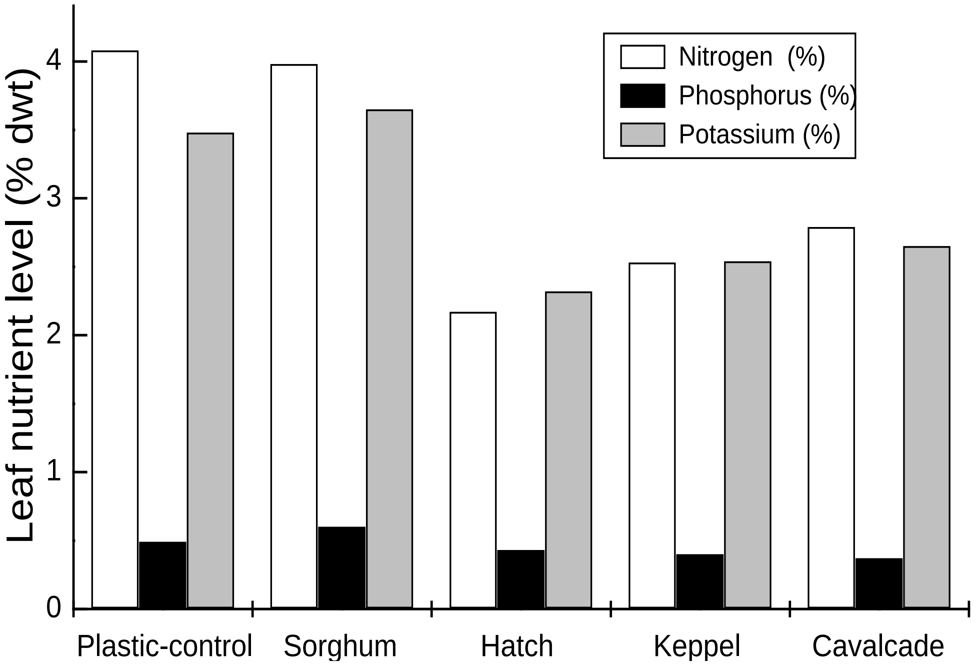
The level of mulch produced by a cover crop was closely related to the plant biomass in dry weight. Plants that provided excellent cover but also contained high water content, produced less mulch than a plant with similar levels of cover but low water content in the plant material. Hence, dry weight biomass figures shown in Figure 1.3 are representative of the levels of mulch left on the soil surface once the cover crop is sprayed off. The best-performed cover crops in dry weight biomass were the Indian Bluegrass varieties (Hatch and Keppel) and *Centrosema cavalcade*. *Brassica napus* varieties did not produce high levels of dry weight biomass due to the "fleshy" nature of the vegetation. Only the Indian Bluegrass and Centro cover crops produced sufficient mulch to cover beds, the cover provided by Brassica treatments was augmented with sorghum straw spread over the beds.

Figure 1.3: Dry matter production of cover crops species.



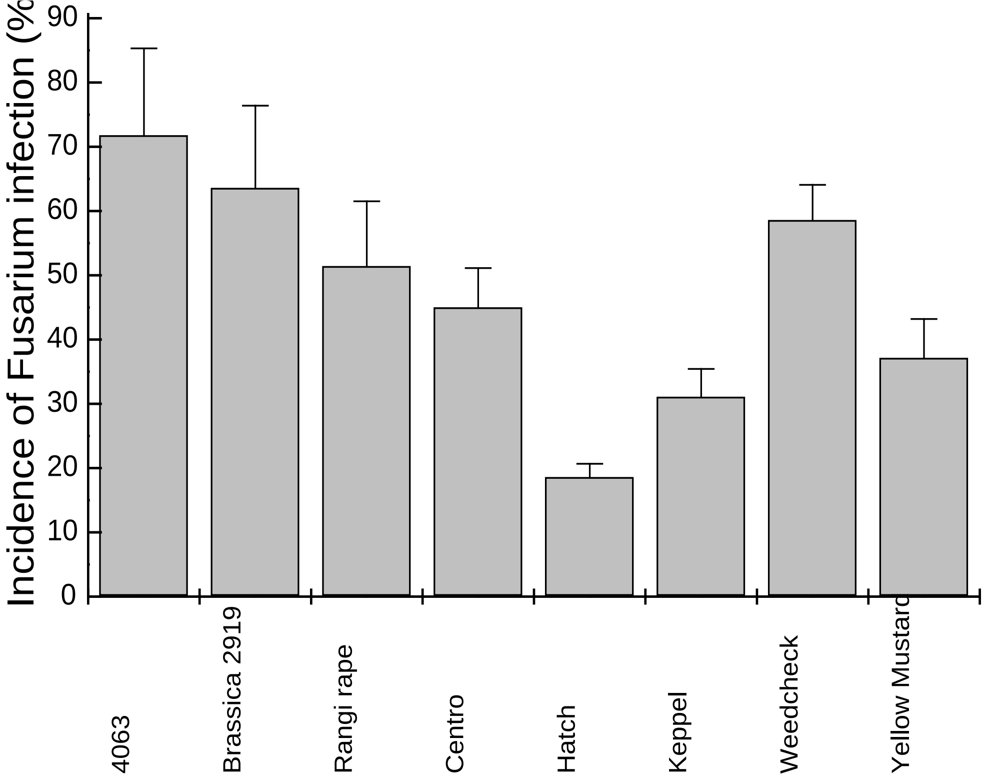
Tomato crops grown following cover crops showed a lower level of nitrogen, phosphorus and potassium within the leaf than either conventional black plastic or transported sorghum mulch. (Figure 1.4).

Figure 1.4: Leaf nutrient levels in Tomatoes "Tempest" planted in various mulch types.



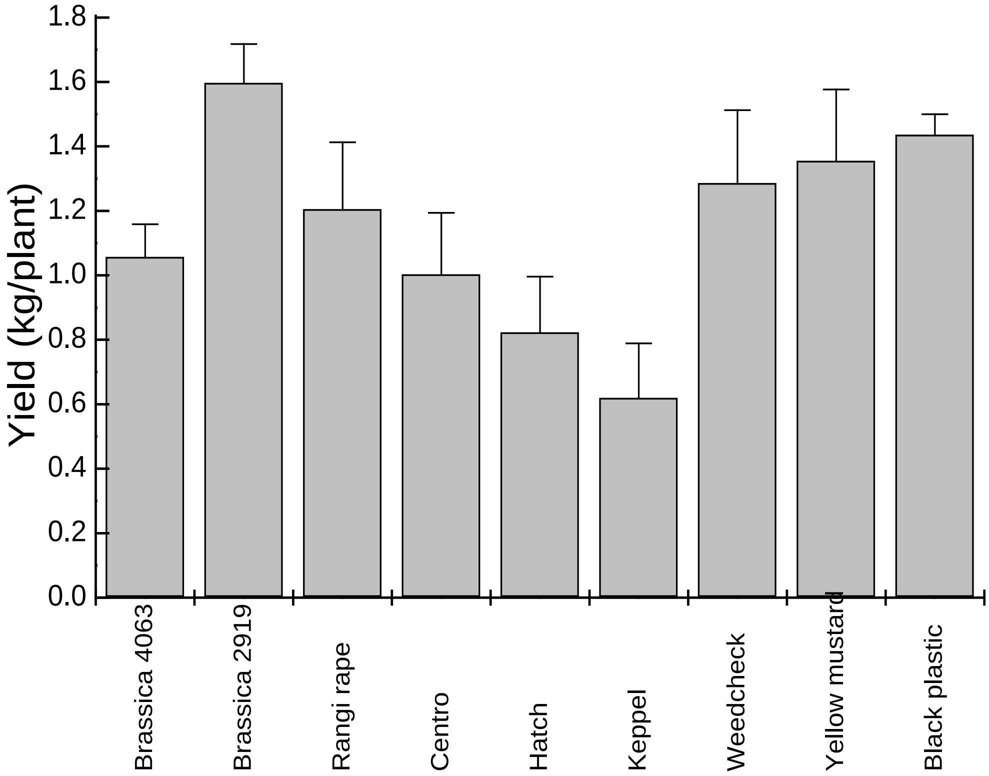
The *Fusarium oxysporum* Race III susceptible tomatoes showed the greatest level of infection under biofumigant mulch rather that the Bluegrass and Centro mulch (Figure 1.5). Fusarium infection was higher on *Brassica napus* varieties 4063 and 2919 followed by Centro and Weedcheck with yellow mustard the best biofumigant whilst the bluegrass varieties showed the lowest levels of infection.

Figure 1.5: Level of infection by *Fusarium oxysporum* (Race III).



The planting of tomatoes into Indian Bluegrass residues resulted in a significantly lower yield relative to the *Centrosema cavalcade* (Centro) mulch and the sorghum covered Brassica plots (Figure 1.6). The cause of this yield decline may be the lower levels of nitrogen and potassium in the leaf relative to the plants grown in Centro mulch and the higher levels of N, P and K under the sorghum mulch.

Figure 1.6: Tomato yields from plants in various cover crop mulches.



Discussion

The most promising cover crops for mulch in this experiment were:
Non-biofumigant plants

- Indian Bluegrass (*Biotrochlea pertusa*) cvv. Hatch and Keppel, and
- Centro (*Centrosema calvacade*)

Biofumigant plants with potential as cover crops in conventional production were:

- *Brassica napus* - KRC 5851
- *Brassica napus* - KRC 837
- *Brassica napus* - KRC 2809
- *Brassica napus* - KRC 2919
- *Brassica napus* - Rangi rape

Cover Crop Assessments – Further Research

Summer 1998-99

A trial of Sunn Hemp (*Crotalaria juncea*) and Pearl Millet was carried out to assess suitability as cover crops. Sunn hemp did not provide sufficient or suitable mulch cover, while Pearl Millet seeded early and was unsuitable for the Dry Tropics region.

Summer 1999-2000

A trial was conducted to evaluate the potential of new mustard varieties alone and in combination cover crops of biofumigants with Centro or Indian Bluegrass var. Hatch. An additional treatment of Centro in combination with sorghum was also included to evaluate sorghum used for early weed control, then sprayed off to allow the Centro to grow and form the mulch. A RCBD experiment was set up composed of 15 treatments. Each plot was 5m long with replication (n=4) across four rows. The combinations evaluated are outlined in Table 1.3.

Table 1.3: Combination cover crop treatments.

Fumus FL	Fumus FE
Muscon	Skymustard
Centro cavalcade + BQ Graze	Indian Bluegrass (Hatch) + BQ Graze
Centro cavalcade + Fumus FL	Indian Bluegrass (Hatch) + Fumus FL
Centro cavalcade + Fumus FE	Indian Bluegrass (Hatch) + Fumus FE
Centro cavalcade + Muscon	Indian Bluegrass (Hatch) + Muscon
Centro cavalcade + Skymustard	Indian Bluegrass (Hatch) + Skymustard
Centro cavalcade + Sorghum	

The Hatch seed did not strike in any plots and hence those treatments including Hatch were abandoned.

The sorghum was sprayed out using Fusilade® when it had reached approximately 50cm high. Before spraying it was noted that the Centro growing in these treatments was less developed than Centro growing in combination with the biofumigants. This was attributed to allelopathy from the sorghum, as the extent of shading out of the Centro was similar in all combination treatments.

All of the mustard varieties grew rapidly and began to set flowers and some seed. In an effort to grow the Centro to maturity, the tops of the mustard plants were routinely removed to a height of around 50cm above ground. This removed the majority of flowers, prolonging seed development and extending the life of the cover crop.

When the Centro had reached maturity, the cover crops were sprayed off using Basta® at 5L/ha and rolled using a rubber-tyre roller to flatten the mustard stems. The Mustard varieties alone formed a poor mulch and were abandoned, whilst the combination plots had thin but reasonable cover of Centro mulch. The poor level of Centro mulch was most likely the result of late sowing as seen in other experiments conducted at the same time (see Experiment 6: Crop Evaluation Experiment) rather than poor Centro performance in cover crop combinations.

Following a 5-week period to allow the cover crop to die and reduce the risk of allelopathy, the experiment plots were planted with Capsicum ver. “Merlin” at 25cm spacings. Capsicums were grown to maturity and harvested twice with the combined results shown in Figure 1.7. No clear trends were observed in the yield results with lower yield of red fruit observed in the Centro + Sorghum and Centro + BQ Graze treatments, whilst the Centro + Fumus FL had lower yield of green fruit and higher levels of damaged fruit. Weed suppression ratings were recorded during crop growth, with the Centro + BQ Graze combination showing improved levels of suppression over the other treatments (Figure 1.8).

Figure 1.7: Yield of Capsicum in combination cover crop experiment.

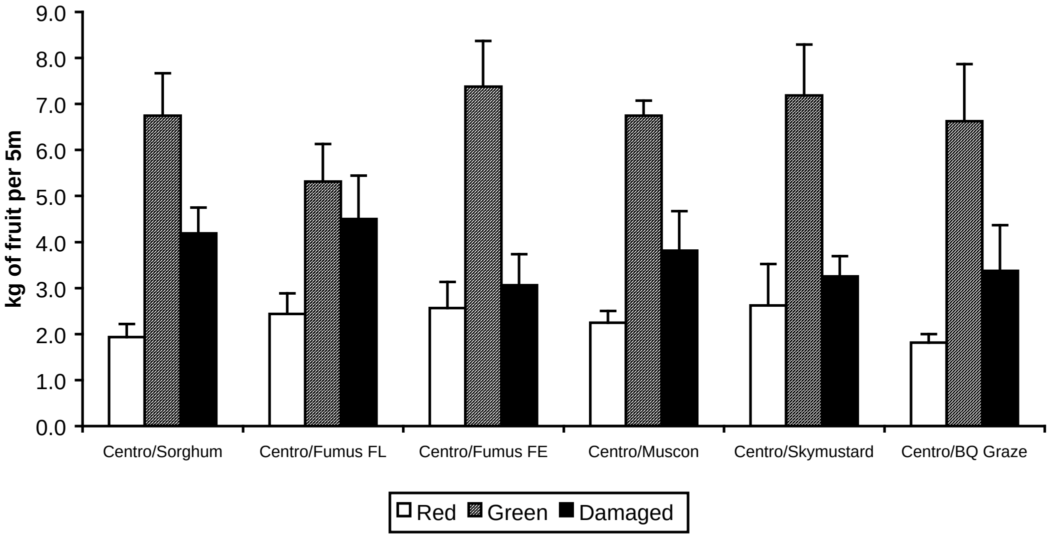
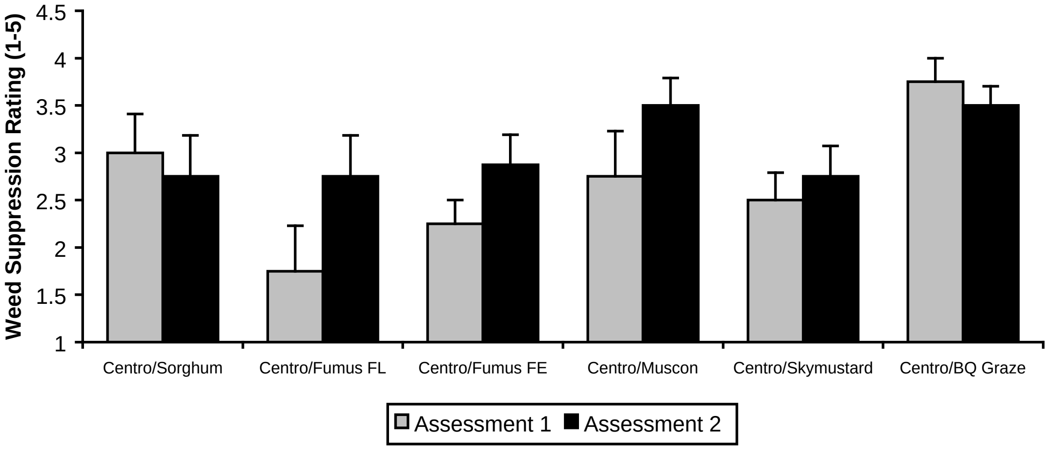


Figure 1.8: Weed suppression ratings of different mulch types.



Winter 2000

A experiment of suitable cover crops to be grown over winter in North Queensland showed some potential, particularly oats, BQ-Mulch (*Brassica napus* type), Shirohie millet and ryegrass. However kangaroos heavily damaged the experiment by continuously grazing the small plots of the grass cover crops and hence the mulch potential of the grass cover crops could not be determined. Other broadleaf cover crops evaluated particularly, BQ-Mulch, Fumus FL and Weedcheck (both mustards), showed potential as short break crops that could be used when an area is not being used over the commercial season.

Discussion of Further Research

There is a strong need for a greater variety of cover crops suitable for use in the Dry Tropics to provide growers with a greater range of choices to suit the requirements of specific crops and situations. Further work could be conducted in manipulating cover crops, in particular sorghum, to provide a relatively cheap and freely available option. The use of biofumigants in this system would be beneficial, however currently available varieties are unsuitable for growing over summer in the dry tropics. Further investigation of leguminous cover crop varieties and manipulation also needs to be undertaken to maintain adequate soil nitrogen levels.

SECTION 2: Cover Crop Assessment – Temperate Region

Introduction

The objective of the cover crop assessments in Richmond NSW were to identify suitable cover crop species for the minimum tillage system in temperate cropping areas. Cover crops were grown over winter in the majority of experiments using cereal crops and biofumigant species. One experiment was conducted over the summer months to determine suitable cover crops for autumn/winter vegetable crops.

Experiment 2.1: Winter 1999

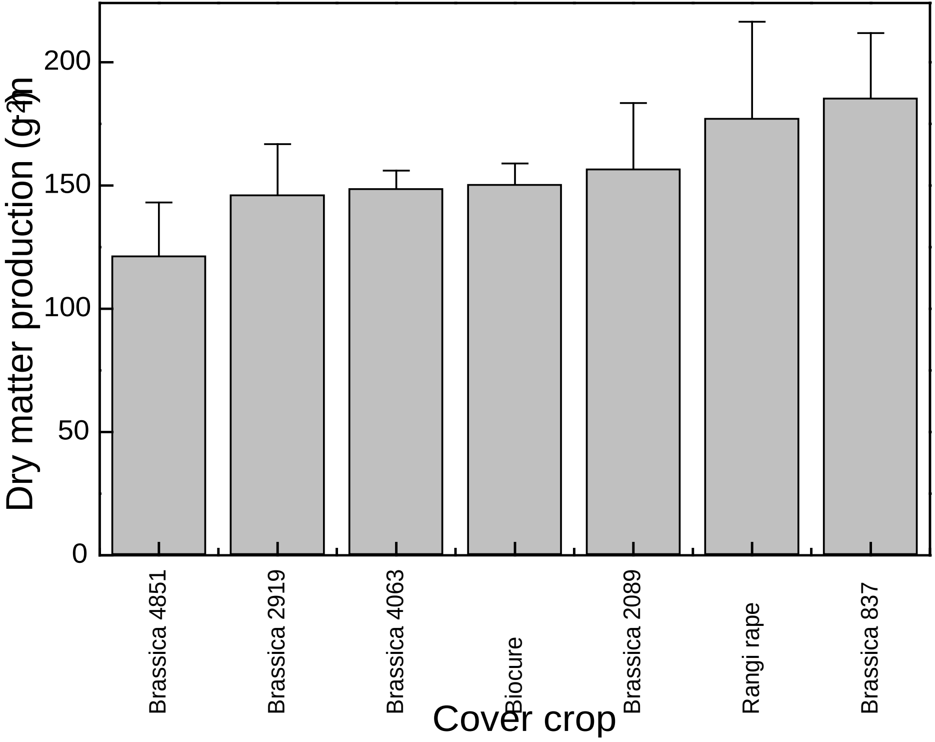
A small-scale experiment was set up in the UWSH-Richmond experiment area to assess the growth and allelopathic effects of Brassica species that were promising at Bowen. The experiment was a Randomised Complete Block Design with seven species of cover crop (n=4): Rangi rape; Biocure (B. *napus* mix); KRC 4851; KRC 2919; KRC 837; KRC 2089; KRC 4063.

All cover crops were broadcast sown by hand or using a hand-held fertiliser spreader and the seed incorporated using a rake. Cover crops were irrigated using solid-set overhead irrigation and crops irrigated using trickle tube laid over the surface of the mulch. The plants were grown using trickle irrigation and also an experimental sub-surface irrigations system known as CRZI. CRZI has potential as a semi-permanent irrigation system with for the permanent bed system. Cover crops were harvested and dry matter measured.

Results

Rangi rape, KRC2089 and KRC 837 produced highest levels of dry weight biomass (Figure 2.1.1). As seen in the cover crop experiments in Bowen, dry biomass produced by the Brassica cover crops was insufficient as a mulch cover.

Figure 2.1.1: Dry biomass production of Brassica cover crops.



Experiment 2.2: Summer 1999/2000

Cover Crop Stage

This experiment was designed to further evaluate cover crops and combinations which were promising north Qld. as well as evaluate some newer biofumigant mustards, which release glucosinolates through the roots, and may potentially be useful in the minimum tillage system. Cover crop species alone and in combination were planted in December 1999. Table 2.2.1 lists the cover crops evaluated.

Table 2.2.1: Cover crop species evaluated at UWSH in 1999/2000.

Indian Bluegrass	Keppel Hatch
Fodder Rapes	Weedcheck KRC 2936 KRC 912 KRC 4880 KRC 2863 Nemfix 8008 Superstrike 3925 Rangi Rape KRC 837 KRC 4851 KRC 4063 BQ mulch 300198 KRC 2809 KRC2919
Clovers	Clover SCO 8006 Berseem clover SCO 8002 Persian clover SCO 8003
Mustards	Yellow mustard Muscon M-973 ISC 9349 Fumus F-L71 V56-868 Fumus F-E75 V56-867
Other Legumes	Centro cavalcade Lucerne
Other Grasses	Jumbo Sorghum Shirohie Millet
Combinations	Hatch + Fumus F-L71 Keppel + Fumus F-L71 Centro + Fumus F-L71 Keppel + Muscon M973 Keppel + KRC 2809 Muscon M973 + Persian clover SC8003 Millet + Muscon M-973 Shirohie Millet + Lucerne Sorghum + Muscon M973 Jumbo Sorghum + Lucerne

The most promising cover crops from the experiment were Shirohie millet alone and in combination with lucerne, lucerne alone and lucerne in combination with sorghum (Figure 2.2.1). The Muscon and Fumus species established and grew well, but bolted to seed very quickly, tropical grasses and legumes did not establish and clovers did not compete with weeds effectively. Fodder rapes provided excellent soil cover when growing but did not provide sufficient mulch cover once killed.

Killing Cover Crops

Once cover crops had reached maturity they where killed off using a variety of means including spraying and spraying in combination with slashing or rolling to determine the advantages and disadvantages of each method. At this point only the experiment areas consisting of rows planted with lucerne alone, and sorghum or millet alone and in combinations with Muscon or lucerne were kept for further work.

Each cover crop was subjected to two separate treatments. One half was sprayed with glyphosate at 4L/ha and then rolled, whilst the other half was slashed and then regrowth sprayed with glyphosate at 5L/ha 20 days later. A further application of glyphosate at 5L/ha was required on the rolled treatments 20 days after the initial treatments.

Figure 2.2.2: Shirohie Millet and Lucerne combination.

Commercial Crop Stage

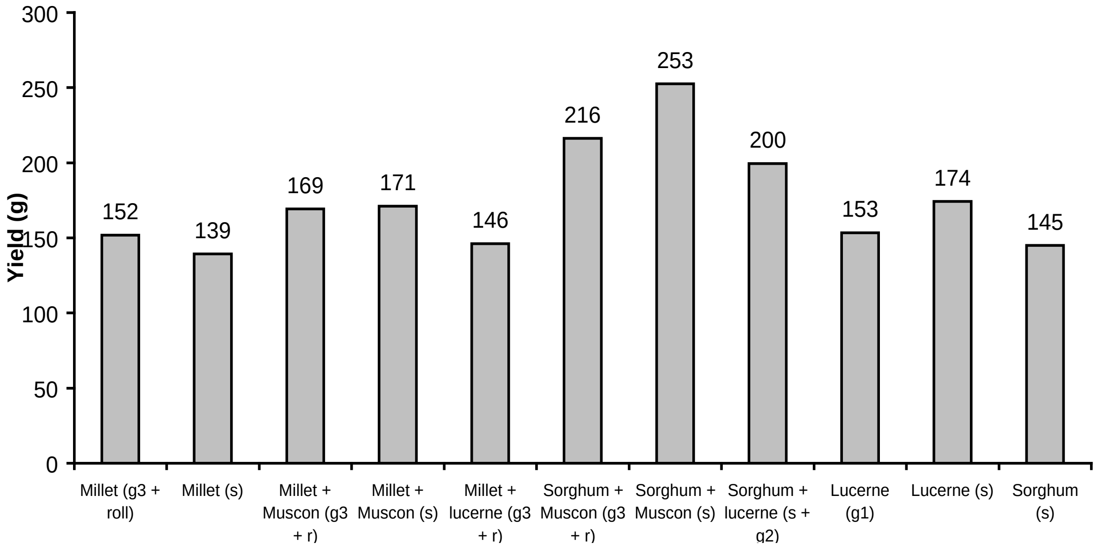
A broccoli crop was then grown in the cover crop residues. Initial assessments found that there was an increase in susceptibility to seedling damping off disease. Many seedlings were lost in the early stages of plant development as shown in Table 2.2.2. Weed control by the mulch was good early on however the lucerne showed some regrowth in both the spray + rolled and slashed + spray treatments.

Table 2.2.2: Seedlings remaining after early plant losses.

Species	Method of killing	Original No plants	Surviving plants (%)
Millet	gly + roll	100	28
	slash + gly	52	88
Millet + Muscon	gly + roll	38	37
	slash + gly	38	58
Millet + lucerne	gly + roll	38	34
	slash + gly	38	53
Sorghum + Muscon	gly + roll	38	47
	slash + gly	38	21
Sorghum + lucerne	gly + roll	38	3
	slash + gly	38	16
Lucerne	gly + roll	38	66
	slash + gly	38	74
Sorghum	slash + gly	76	38

Average growth rates over the length of the experiment showed that broccoli grew best in millet or millet + muscon that had been slashed rather than rolled whereas growth was greater where millet + lucerne was rolled rather than slashed. Yield results per plot showed high variation due to the loss of plants to damping off early in the experiment, however mean yield per plant (see Figure 2.2.1) showed that the majority of the treatments produced similar yields with the exception of the sorghum + muscon (rolled), sorghum + muscon (slashed) and the sorghum + lucerne (slashed) treatments which showed higher yields per plant than all other treatments.

Figure 2.2.2: Mean yield per plant of broccoli planted into cover crop residues



Experiment 2.3: Summer 2000/01

Cover Crop Stage

The experiment focussed on six cover crops and the use of the crimping roller to kill them following flowering. The cover crops used were forage sorghum, ryegrass, oats, wheat, shirohie millet, and lucerne. The cover crops were planted on the 9th of September 2000.

The killing of the cover crops investigated the potential of the crimping roller alone and in combination with a glyphosate spray. Rolling of cover crops has been used in US minimum tillage systems with much success, hence a design for a cover crop roller was obtained from Dr. Aref Abdul-Baki of the US Department of Agriculture and a roller constructed for use in these experiments.

The spraying and rolling was timed to coincide with late flowering in the grasses, however sorghum and lucerne had not the reached flowering stage by the time they were rolled. Cover crop plots were split into two halves; one half was sprayed with glyphosate at 4L/ha on the 8th of December with the other half left unsprayed. Each half was then rolled three days later using the crimping roller.

Table 2.3.1: Killing methods tested and results observed.

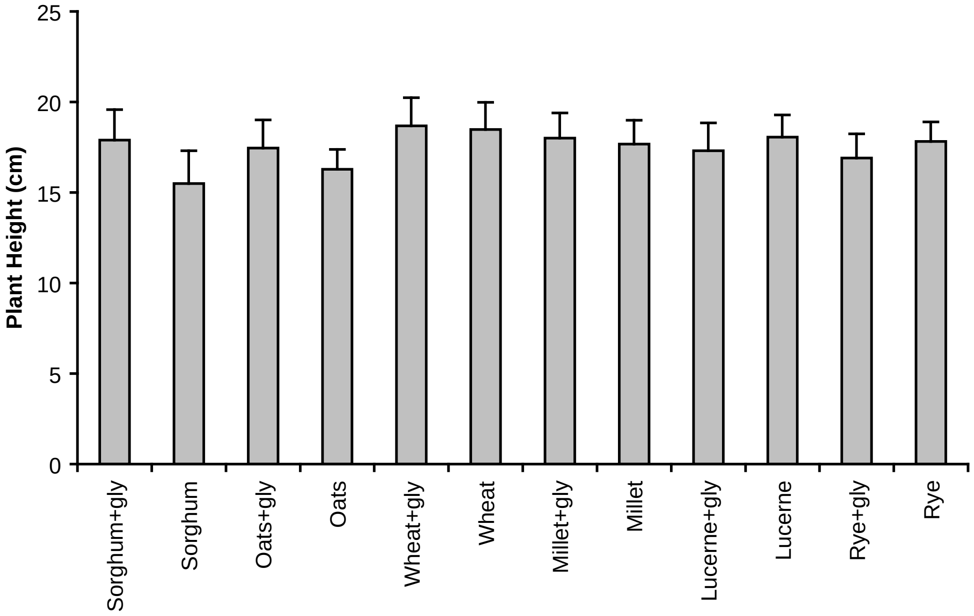
Cover crop	Method of killing	Observations
Forage sorghum (var. Jumbo Pacific)	Rolling	Rolling alone did not kill cover crop.
	Herbicide (glyphosate) then rolling	Herbicide plus rolling was effective and produced a dense matt of mulch.
Oats (var. Racehorse No.1)	Rolling	Rolling alone effective at killing cover crop.
	Herbicide (glyphosate) then rolling	Herbicide plus rolling effective at killing cover crop.
Ryegrass (var. Surrey Heritage)	Rolling	Rolling alone moderately effective. Follow up herbicide needed on rolled areas.
	Herbicide (glyphosate) then rolling	Herbicide plus rolling effective at killing cover crop.
Forage Millet (var. Shirohie)	Rolling	Rolling alone effective at killing cover crop.
	Herbicide (glyphosate) then rolling	Herbicide plus rolling effective at killing cover crop.
Wheat	Rolling	Rolling alone effective at killing cover crop.
	Herbicide (glyphosate) then rolling	Herbicide plus rolling effective at killing cover crop.
Lucerne (var. Aurora)	Rolling	Not effective
	Herbicide (glyphosate) then rolling	Not effective

The cover crops where rolling alone was not effective in killing the plants were treated with glyphosate at 5L/ha four days after rolling had taken place.

Commercial Crop Stage

Broccoli seedlings (var. Shilo) were planted by hand through the mulch covers seven days after cover crops were rolled. Vegetative plant growth data was recorded.

Figure 2.3.1: Broccoli plant height 45 days after planting.



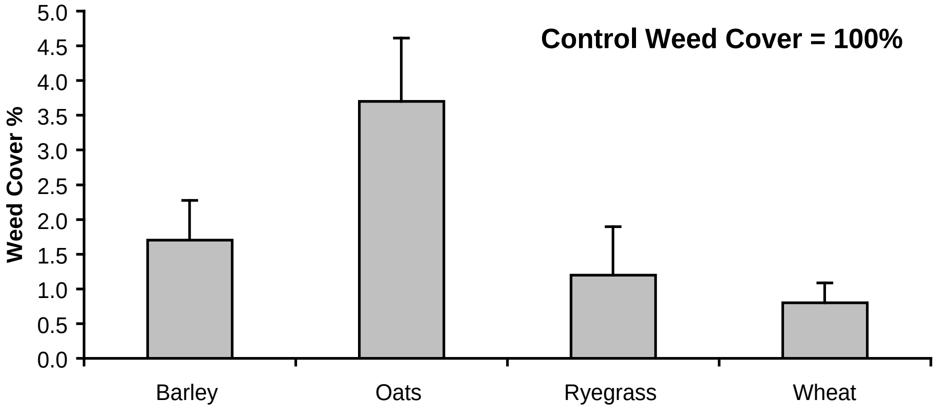
Sorghum treatment that was initially only rolled showed some growth suppression, however the majority of the treatments were statistically similar.

Experiment 2.4: Winter/Spring 2001

Cover Crop Stage

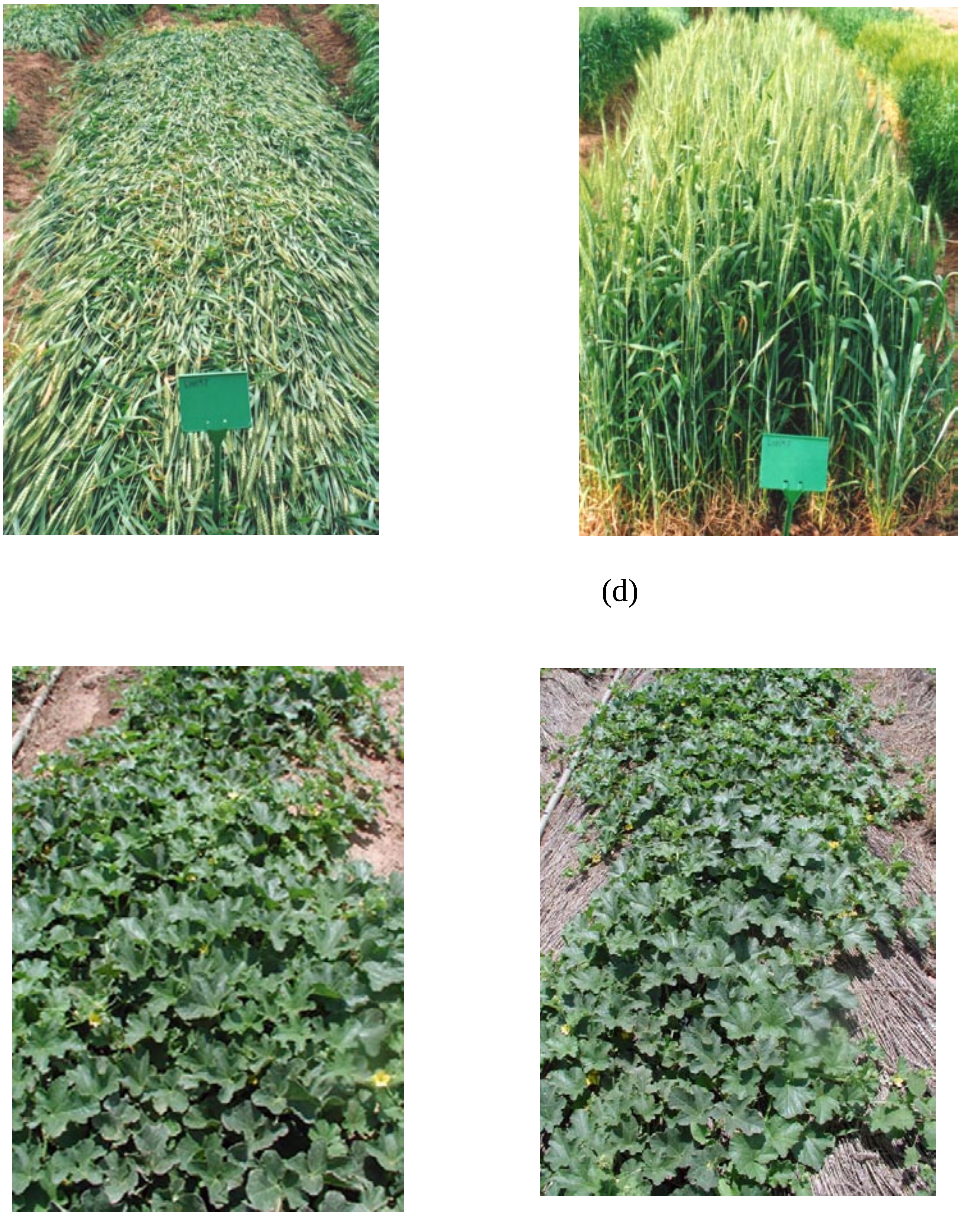
Cover crops of Rye, Wheat, Oats and Barley were sown and compared to bare soil in a RCBD experiment over the winter of 2001. Bare soil treatments had weed cover during cover crop growth of almost 100% (data not shown), significantly higher than Oats treatments where weed cover averaged 3.7%, significantly lower again were the Barley, Ryegrass and Wheat treatments with 0.8-1.7% weed cover as shown in figure 2.4.1.

Figure 2.4.1: Percentage weed cover in cover crop stands.



Cover crops were sprayed with Glyphosate at 4L/ha using a knapsack after 18 weeks of growth, rolled the following day (see Figure 2.4.2) and planted a day after rolling. Around half of the seedlings planted were lost to a *Pythium spinosum* and other Pythium species within the first 7 days. Plants lost were replanted with new plants 10 days after the original planting date.

Figure 2.4.2: Wheat cover crop before (a) and after (b) rolling. Rockmelons growing in bare soil (c) and in wheat residues (d).



a)

b)

(c)

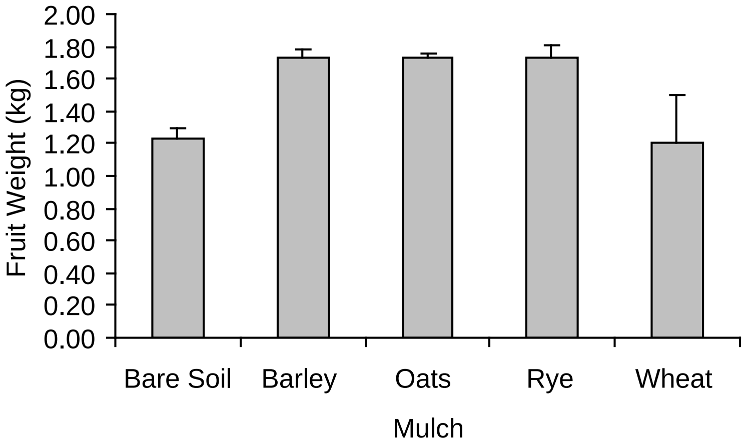
(d)

Commercial Crop Stage

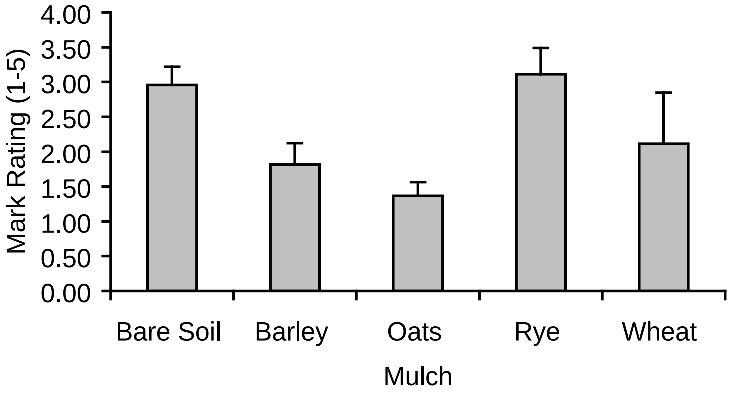
Rockmelons are currently growing (at the time of writing) in these mulches and are doing well. Preliminary data is presented on initial harvests. were grown using conventional agronomy with irrigation decisions being based on the soil moisture status of the mulched plots rather than the bare soil treatments. Weeds were chipped out of the bare soil plots following assessments, to enable rockmelons to grow without competition.

Figure 2.4.3. Fruit weight (a), surface damage (b) and fruit diameter (c) of the initial 2 harvests from rockmelon (var. Eastern Star) growing in various mulch residues at Richmond, NSW.

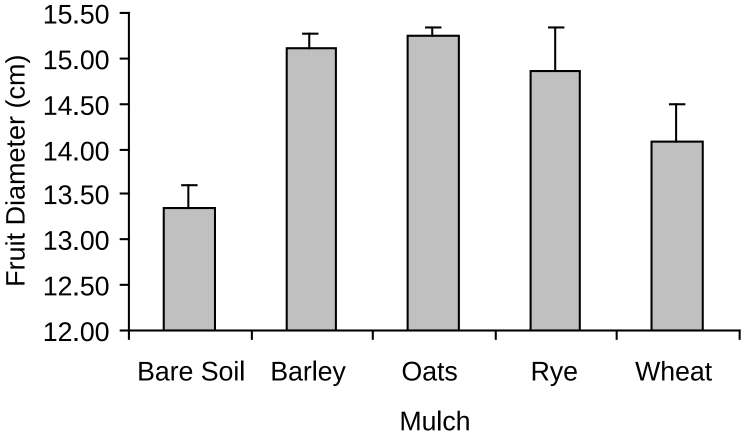
(a)



(b)



(c)



Discussion

The best performing cover crops for western Sydney and other regions in New South Wales were:

Spring/Summer cover crops
- Shirohie Millet
- Wheat

Autumn/Winter cover crops
- Wheat
- Barley
- Oats

These cover crops all form a thick and stable mulch, are readily killed using herbicides and rolling, and do not cause suppression in the following commercial crop.

Forage sorghum has some potential but the mulch formed is typically composed of thick stems, which are difficult to plant through. Lucerne performed well but is too difficult to kill using glyphosate but may respond better to other chemicals such as MCPA or Dicamba. Ryegrass has performed well but typically forms a dense mat of roots on the soil surface that can be difficult to penetrate when transplanting.

SECTION 3: Commercial Scale Production – Bowen

Introduction

All production areas were sown with cover crops and scheduled for commercial production for the 2000 season. By conducting the research on a commercial scale advantages and disadvantages of the system can be assessed at a more practical level. It is the experiences gained from the two seasons of commercial experiments that have helped to construct the growers guide to establishing the permanent bed system which forms section 2 of this report.

1999/2000 Activities

Cover Crop Stage

In preparation for the 2000 cropping season, the beds on hydrant 23L were ripped down the centre to improve the soil condition for transplanting.

Once the beds had been ripped, superphosphate was applied at 600kg per hectare banded down the centre of the beds.

The cover crop was sown on hydrant 23L in December 1999. One half of the hydrant was sown with Centro in 6 drills per bed using the straw planter, at a rate of 25-30kg/ha. The other half of the hydrant was sown with Keppel mixed with sawdust and spread using a Vikon ® spreader at approximately 5-7kg of Keppel seed per hectare. The half hydrant sown with Keppel was irrigated overhead for 7 hours and the entire block was then sub-surface irrigated for 18 hours. Following the Christmas/New Year break, an inspection of the site showed that no Keppel seed had germinated; it has been assumed that the seed used had been stored inappropriately. The failed section was sown with Centro on 1st February.

Work on hydrants 1&2 commenced in January with trickle tape and an end manifold system being installed in both hydrants. Whilst the irrigation tape was installed, the sub-surface risers were buried deeper underground to enable machinery to pass over the top without damaging the irrigation pipe. Superphosphate was applied to both hydrants at 600 kg/ha prior to sowing the cover crop. Hydrant 2 was sown with Centro in 6 drills per bed using the straw planter on 27th January with hydrant 1 being sown with Centro on the 1st February.

Heavy rainfall occurred over the first week of February, however due to the stability of the soil on the permanent beds minimal erosion occurred even on the exposed soil of hydrants 1&2. Some material was lost on hydrant 23L where the beds had been ripped down the centre; water appeared to have concentrated in the centre of the bed and washed out some material as it flowed down the row.

The Centro sown in December on hydrant 23L was the first area of cover crop to be sprayed off on 31st March. Two herbicides were experimented, 9 rows were sprayed with glyphosate (360 g/L) at 6 litres per hectare using an air boom whilst 11 rows were sprayed with Basta® at 5 litres per hectare. The kill from these applications was approximately 95% for both treatments with the glyphosate acting slower but more systemic whilst the Basta® killed off most of the above ground biomass rapidly but regrowth occurred from underneath the dead material.

The remaining areas of cover crop began to flower in May; biomass cuts were taken before the cover was sprayed off with results shown in Table 3.1.1. Biomass levels were roughly equivalent with higher biomass on the late sown area of hydrant 23L, possibly due to an application of 50kg/ha of Urea 6 weeks before spraying and the lighter soil texture. An estimate of the biomass present on the top side of hydrant 23L before spraying would be 8-9000 kg D.M./ha.

Table 3.1.1: Biomass cuts taken on 11th May.

Hydrant 23L (Bottom)	Hydrant 1	Hydrant 2
7612 ± 151 kg.DM/ha	6407 ± 474 kg.DM/ha	6872 ± 333 kg.DM/ha

The mulch formed by the sprayed off cover crop did not conform to the biomass figures shown above. The thickest and most coherent mulch was found where Centro had been sown in December on hydrant 23L (see Figure 3.1.1), the mulch in this area was still superior to other areas despite the majority of the material being sprayed 5-6 weeks earlier than the other areas. In contrast the mulch on the lower side of 23L was thinner and less dense than all other areas despite having higher biomass figures. This was due to high populations of weeds during the growth of the cover crop and a lower sowing rate. Mulch cover on hydrant 2 was good with sufficient ground cover in most areas albeit thinner than the mulch on the top side of 23L. Cover on hydrant 1 was thinner again than hydrant 2. Significant competition throughout the cover crop growth was observed from Pigweed (*Portulaca oleracea*) and other weeds and a lower sowing rate.

Despite the mulch cover, all areas of the experiment required weed control prior to and during the commercial crop. Inter rows and in some areas, particularly hydrant 1 and the bottom of 23L, required spraying with Spray Seed® prior to planting of the crop and in some cases a further treatment early in the crop with either Basta® and/or Sencor® for post emergent and pre emergent weed control.

Figure 3.1.1: Mulch cover on Hydrant 23L.

Commercial Crop Stage

Soil tests taken prior to planting of the tomato crop showed adequate levels of most nutrients with the exception of Potassium and Nitrogen, this deficiency was corrected by fertigation with potassium nitrate. Phosphorus levels were excellent showing the benefit of applying superphosphate before planting the cover crop.

Tomato crops were planted in all areas as per the details in Table 3.1.2. Seedlings were planted using a conventional water wheel planter with extended and sharper spikes to punch through the mulch rather than pushing the mulch into the hole.

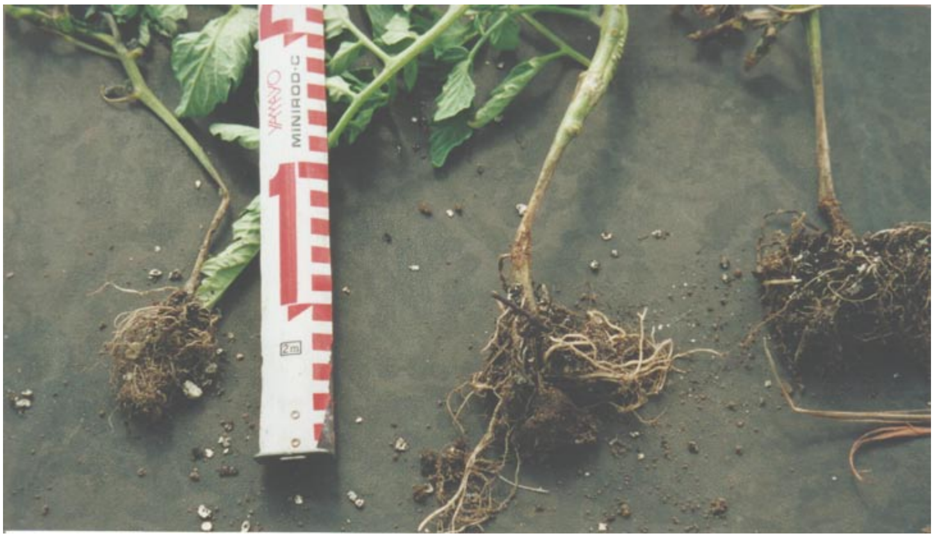
Table 3.1.2: Planting dates and tomato varieties used.

Location:	Hydrant 23L	Hydrant 1	Hydrant 2
Variety:	Commando (Egg)	Qld. Red (Round)	Grenade (Egg)
Planting Date:	12th July	17th July	24th July

An early problem was the loss of a number plants due to a fungus on the stem close to soil level (see Figure 3.1.2), not all plants were affected but many plants were lost during the early stages of growth to what was identified as a type of *Phythophora.* Various factors are attributed to this problem including the depth of the hole for the seedling, organic material falling into the hole, and high moisture levels surrounding the plants stem. A combination of all these factors is believed to be the cause of the problem.

Early crop growth was inhibited by exceptionally cold weather, and as the temperature increased the organic mulch continued to keep soil temperatures low, around 4-5°C cooler than under black plastic. Anecdotal evidence showed that the organic mulch promoted frost forming on beds, a experiment treatment with molasses sprayed onto the mulch showed that the molasses prohibited frosts forming in the short term but the longevity of such a treatment could not be tested. A further inhibitor of crop performance was the use of conventional irrigation scheduling which frequently left the upper levels of the soil quite dry; a change in the watering regime resulted in improved vegetative growth.

Figure 3.1.2: Seedling "damping off" observed in Hydrant 2.



Problems of weed control were an issue as the crop aged, tall growing weeds such as milk thistles; blackberry nightshade and wild gooseberry were especially troublesome. Most weeds grew in amongst the tomato bushes although some low growing weeds grew on the edges of the beds where mulch cover was thin. The major problem areas were the bottom side of 23L where the mulch was very thin, hydrant 2 where milk thistles were prolific (thistles had also grown and seeded during the growth of the cover crop), and Hydrant 1 where low growing weeds emerged through the thin mulch. Figure 3.1.3 shows tomato plants on Hydrant 23L at 7 weeks after transplant.

Figure 3.1.3: Tomato plants – Hydrant 23L.

Results

Fruit yields from hydrant 23L were encouraging. Fruit picked monitored through the packing shed. Observations by packing shed staff suggest that the fruit had excellent size but lacked both the volume and quality of fruit grown under the conventional system. Quality issues focussed mainly on fruit appearance, which was poor with most fruit scratched or scarred. Hydrant 23L was picked for a total of four times, fruit picked on the first pick was marked, probably from contact with the mulch, but subsequent picks were also marked although the reasons for this is unclear as there could be no contact with the mulch due to trellising. Most of the fruit picked on the fourth and final pic was discarded and the hydrant abandoned, however fruit remaining on the bushes was extensive with exceptional size for a crop that had been picked 4 times previously. Fruit harvested late 2001 showed a similar surface mark.

Fruit quality was again an issue on Hydrant 1 although this was a combination of scratching and the poor performance of the variety in general. Fruit was once again large but scratching and some breakdown of colouring fruit in the field (common to the variety) led to the hydrant being abandoned after the first pick. Fruit from hydrant 2 was also heavily marked, although once again size was excellent. The hydrant was abandoned after 2 picks; residual fruit on the bushes again showed good size.

A direct comparison of yield between conventional and permanent bed systems was conducted and the data presented in Tables 3.1.3 and 3.1.4. It is important to note however that each commercial block is individually managed and harvested and hence any direct comparison must be studied in light of this. The results shown graphically in Figures 3.1.4 and 3.1.5 are based on the average of four replicates of small plots that were individually picked and weighed. As Hydrant 17L, the plastic control area, was picked a total of 6 times compared to Hydrant 23L which was picked 4 times a residual pick was taken after each block was abandoned to estimate the residual yield that had not been commercially picked. Residual yields were high on the permanent bed areas due to them being abandoned prematurely, whilst residual yield on the plastic control was low as it had been completely stripped of commercial sized fruit. The addition of the residual picks to the estimated total yields bring the permanent bed harvests much closer to the total harvest of the plastic control and begins to show that yield differences between the two systems are not a great as the commercial yield data suggests.

Discussion

With the objective of a commercial crop being grown under the permanent bed system being realised further investigation must focus on fruit quality, plant nutrition and irrigation management in order to establish why commercial yields are currently lower and fruit quality poor under a minimum tillage system. Ideally plant stress should be kept to minimum to promote maximum commercial yield, stresses caused by temperature and water availability throughout the crop is the most logical explanation of the poor fruit quality observed this season. With further research into the management needs of the commercial crop, particularly irrigation and plant nutrition, and the continual improvement of soil physical properties under the permanent bed system commercial yields should improve as seen in similar systems internationally.

Table 3.1.3: Summary of Commercial Yield Data

Hydrant 23L **Rows: 39**
Variety: Commando **Area: 1.21**

	Pick Date	Packing Date	Bins Picked	Gas Room	Returns	Cartons
Pick 1	1/10/00	11/10/00	26	21	5	289
Pick 2	12/10/00	19/10/00	24.5	19	11	261
Pick 3	20/10/00	26/10/00	35.5	16	7	129
Pick 4	26/10/00	3/11/00	16	9	4	73
Pick 4	27/10/00	3/11/00	41	28	10	303
		Total	**143**	**93**	**37**	**1055**
		Total / ha	**118.2**	**76.9**	**30.6**	**871.9**

NB: Final pick abandoned due to fruit quality.

Hydrant 2L **Rows: 29**
Variety: Grenade **Area: 1.16**

	Pick Date	Packing Date	Bins Picked	Gas Room	Returns	Cartons
Pick 1	11/10/00	18/10/00	9	7	*	78
Pick 2	20/10/00	26/10/00	10.5	8	2	138
Pick 2	20/10/00	27/10/00	39.5	20	*	392
Pick 3	22/10/00	28/10/00	11	7	*	122
		Total	**70**	**42**		**730**
		Total / ha	**60.3**	**36.2**		**629.3**

NB: Hydrant abandoned due to fruit quality.

Hydrant 2L&R **Rows: 24**
Variety: Grenade **Area: 1.06**

	Pick Date	Packing Date	Bins Picked	Gas Room	Returns	Cartons
Pick 1	28/10/00	3/11/00	67	41	18	756
		Total	**67**	**41**	**18**	**756**
		Total / ha	**30.2**	**18.5**	**8.1**	**340.5**

NB: Hydrant abandoned due to fruit quality.

Hydrant 1 **Rows: 88**
Variety: Qld Red **Area: 2.79**

	Pick Date	Packing Date	Bins Picked	Gas Room	Returns	Cartons
Pick 1	9/10/00	14/10/00	64.5	52	3	1018
Pick 2	11/10/00	19/10/00	13	12	0	186
		Total	**77.5**	**64**	**3**	**1204**
		Total / ha	**27.8**	**22.9**	**1.1**	**431.5**

NB: Hydrant abandoned due to fruit quality.

Hydrant 17L - Plastic Control
Variety: Commando
Rows: 24
Area: 1.06 245.4

	Pick Date	Bins Picked
Pick 1	5/10/00	30
Pick 2	11/10/00	42
Pick 3	15/10/00	50
Pick 4	18/10/00	28
Pick 5	22/10/00	42
Pick 6	25/10/00	47
	Total	**239**
	Total / ha	**225.5**

Table 3.1.4: Summary of yield data from Permanent Bed experiments with comparison to Plastic Control

	Average Pick per Metre (kg)		**Total Pick per Hectare (tonnes)**		**Average Pick per Hectare (tonnes)**		**Residual Pick per Metre (kg)**		**Residual Pick per Hectare (tonnes)**		**Average Pick - Bins per Hectare**	**Total Pick - Bins per Hectare**	**Total Pick - Cartons per Hectare**
	Avg.	s.e.	Avg.	s.e.	Avg.	s.e.	Avg.	s.e.	Avg.	s.e.			
Hydrant 23L	2.84	0.31	61.9	4.9	15.8	1.7	5.90	0.24	32.8	1.3	29.55	118.2	871.9
Hydrant 2R & 2L	2.68	0.21	59.2	4.0	14.9	1.1	3.81	1.04	21.2	5.8	22.63	90.5	969.8
Hydrant 1R & 1L	1.85	0.19	10.3	1.0	10.3	1.0	*	*	*	*	27.80	27.8	431.5
Hydrant 17L - Plastic Control	3.29	0.43	103.3	8.3	18.3	2.4	2.00	0.15	11.1	0.8	37.58	225.5	*
	Based on replicated small plots										Based on commercial harvest		

Figure 3.1.4: Comparison of Total Yield Picked.

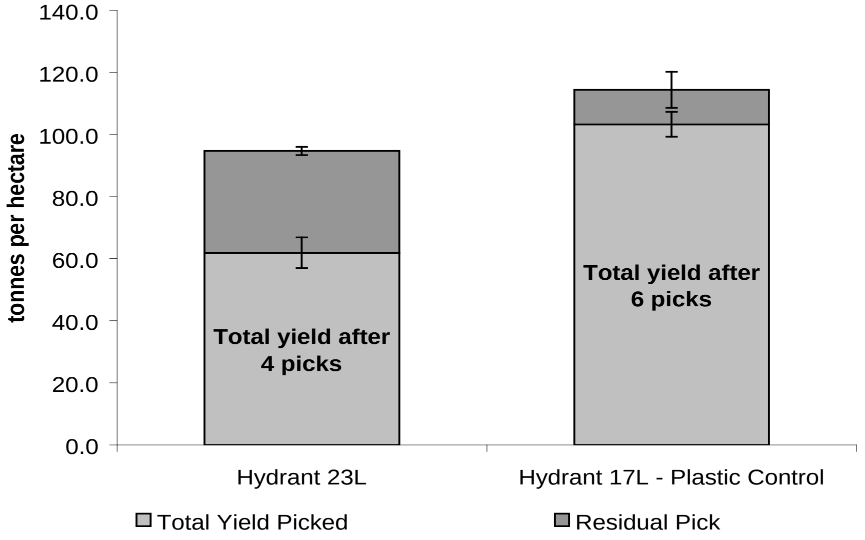
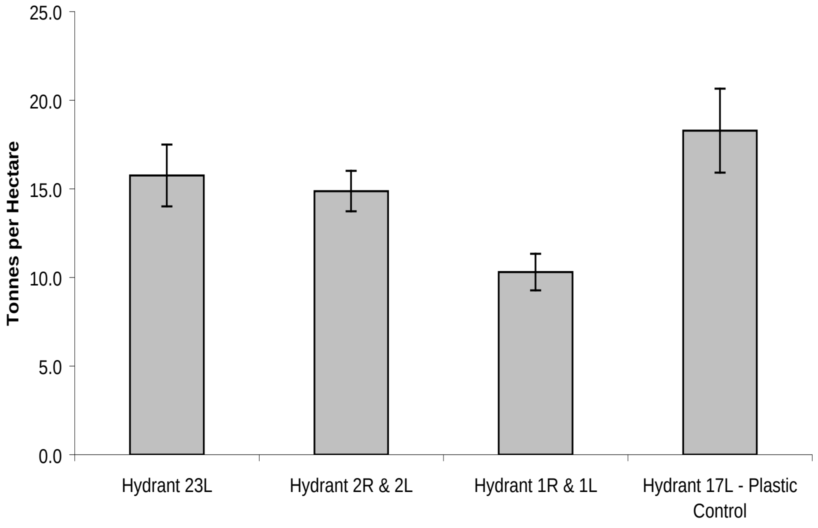


Figure 3.1.5: Average yield per pick.



2000/2001 Activities

Description of Activities

No modifications were made to the beds or their irrigation systems in any of the commercial production areas in preparation for the 2001 tomato season. However a range of experiments were conducted throughout the cover crop stage including a comparison of base fertilisers, the sowing of Indian Bluegrass var. Keppel and a combination planting of sorghum and Centro cavalcade, the use of Jaguar® selective herbicide in Centro cover crops, the use of dual salt glyphosate on both Centro and Bluegrass cover crops, and the experiment of a new method of planting seedlings.

Base Fertiliser Experiment

Each fertiliser used in the experiment was spread over half a hydrant as outlined in Table 3.2.1. Soil samples taken at the same stage last year were compared to samples taken from each area in May 2001. The comparisons show that no fertiliser treatments produced a significant increase in soil nutrient levels. This would indicate that nutrients released from the mineral components of the fertilisers had only countered the nutrients lost in last years crop.

Table 3.2.1: Fertiliser treatments evaluated.

Base Fertiliser	Block	Rate	Composition
Nutritech Custom	H1R	3.5 t/ha	8% C, 8% Ca, 3.5% K, 7% S, 0.8% N, 0.6% P, 0.6% Si, 0.7% Fe, 0.2% Mg
EM/Power Organics	H1L	3.5 t/ha	Pig Manure treated with EM-1
Rock Phosphate	H2R	2.0 t/ha	28% Ca, 11.5% P
AgSolutions Natra-Min Hi Phos	H2L	2.0 t/ha	22% Si, 11% Ca, 4.7% Fe, 2.4% K, 2% P, 2.5% S, 1.7% Mg
Nutritech Custom	H23L	3.5 t/ha	As Above
Rock Phosphate	H23L	2.0 t/ha	As Above
Nutritech + EM/Power Organics	H1L (top 9 rows)	3.5/ha	As Above

Cover Crop Experiments

Indian Bluegrass var. Keppel was sown in Hydrant 1L using peat moss which had been shredded, then mixed with the keppel seed in a cement mixer at a ratio of 300g of seed per 20L bucket of peat moss. The mixture was then broadcast sown by hand although seed would preferably be spread mechanically. The seed was then lightly incorporated using rolling cultivators.

A combination cover crop of Centro and forage sorghum was sown in Hydrant 1R in an attempt to achieve a fast soil cover to prevent weed emergence using the the sorghum, which would then be sprayed off to allow the slower establishing Centro to grow over the top. Centro was sown using the no-till seeder at 25kg/ha whilst the sorghum was sown using a Conner-Shea disc planter at 40kg/ha. The sorghum was sprayed out using Fusilade® at 4L/ha once flowering had commenced. The timing of spraying was too late and the surviving Centro plants had been stunted by the shading and competition of the sorghum. Once the sorghum had died off, the Centro grew rapidly, trellising on the dead sorghum stems. The Centro was sprayed off using Basta once flowering had commenced, however there was insufficient cover produced to provide weed control for the following tomato crop and the area was instead planted with a Triticale winter cover crop.

Centro cavalcade was sown in Hydrants 2L, 2R and 23L using the no-till seeder.

Jaguar® Selective Herbicide Experiment

Within Hydrants 2L and 2R a large population of sow thistle had established. This weed had been presnt in small numbers in the 1999 season and had expanded rapidly with high populations present in the 2000 tomato crop. It was decided to attempt to control this species using Jaguar® selective herbicide (250g/L Bromoxinil, 25g/L Diflufenican) used to control a range of broadleaf weeds in cereal crops and leguminous pastures.

Jaguar® was applied using the air assisted boom at the maximum label rate of 1L/ha. A week after spraying many of the sow thistles and volunteer tomato seedlings had begun to die off which continued into the second week where all sow thistles and tomato seedlings had died completely. However by this stage the Centro was showing signs of damage with young leaves curling up and dying and older leaves turning pale yellow, then white (see Figure 3.2.1). By four weeks however, the Centro plants had begun to recover and by 6-8 weeks no damage was visible at all. Visual assessment of cover crop biomass at killing off stage was only slightly less than in hydrant 23L where no Jaguar® had been applied showing that the Centro had made a complete recovery.

Dual Salt Glyphosate Experiment

Hydrant 1L (Keppel) and Hydrants 2L, 2R and 23L (Centro) were all sprayed with a new formulation Dual Salt Glyphosate to kill off the cover crops. Details are given in Experiment 8: Herbicide Experiments – Bowen.

Figure 3.2.1: Damage to Centro as result of spraying Jaguar®

Modified Planting Technique

A different transplanting planting technique was used in all commercial crop areas in 2000/2001. The method used a large cutting disc which cut through the mulch in the centre of the bed as well as cutting through the soil to a depth of around 15cm. Following behind the disc was a small boot which opened a furrow approximately 5cm wide and 5cm deep (Figure 3.2.2). This was then followed up by a modified cup planter, which then transplanted the seedlings into the open furrow, which was then closed up by the press wheels at the back of the planter. The success of this technique in planting seedlings was good, however the cutting of the mulch and exposure of bare soil encouraged weed germination within the plant row leading to competition and crop damage. Some small areas within the commercial block had the furrows filled by either Vermicast or shredded cane tops (Figure 3.2.3) to evaluate levels of weed control and plant health.

Commercial crop production data could not be followed through to harvest due to time constraints and the conclusion of the project. However, commercial crops of Roma type tomatoes and Gourmet tomatoes were planted and grown to commercial harvest.

Figure 3.2.2: Cutting disc and boot assembly.

Figure 3.2.3: Furrow filled with shredded cane tops.

SECTION 4: Changes in Soil Quality - Bowen

Introduction

The use of minimum tillage and organic mulches has the potential to improve soil structure and soil biological activity. Assessments were conducted to quantify the changes in soil quality comparing soil under the minimum tillage regime relative to soil from areas being farmed using conventional levels of tillage.

Soil sampled from areas under the minimum tillage system was compared to soil sampled from conventional production areas and soil sampled from an uncultivated pasture area directly adjacent to the experiment areas

Table 4.1: Treatment Descriptions

Treatment	Description	Cultivations
Plastic	Soil sample taken from below plastic mulch. Regular cultivation with cover crop sown between vegetable crops.	2 x disc plough passes 1 x harrow 1 x rotary hoe
Native	Soil not farmed	nil
Centro	Cover crop seed drilled directly into stubble	nil
Hatch	Cover crop seed drilled directly into stubble	nil
Keppel	Cover crop seed drilled directly into stubble	nil
Sorghum	Cover crop seed drilled directly into stubble	nil
Sorghum Mulch	Sorghum mulch placed over the soil surface.	nil

Results

Soil Organic Carbon

Soil organic carbon levels were maintained using *Centrosema* sp. mulch but have declined under plastic mulch over 2 years. Soil organic matter levels decline lost rapidly using plastic mulch.

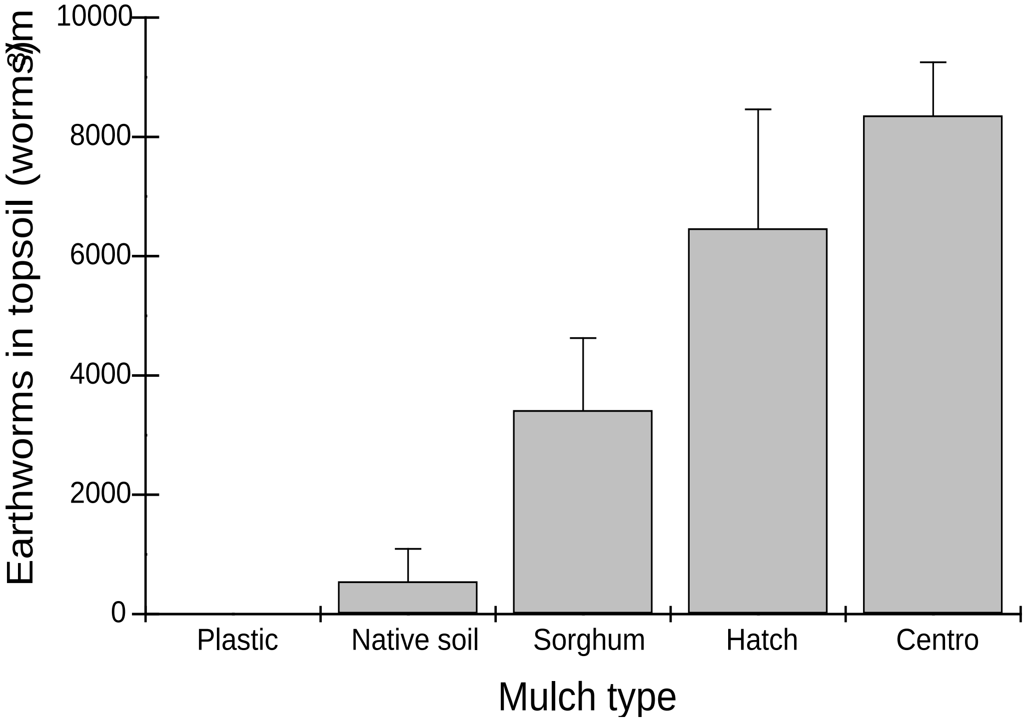
Table 4.2: Changes in Organic Carbon

	Soil organic matter (% - Walkley Black)		
Treatment	1997	1998	1999
Centrosema	1.5	1.20	1.45
Bluegrass cv. hatch	"	1.39	1.20
Bluegrass cv. Keppel	"	1.12	1.06
Plastic mulch	"	1.20	1.00
Inter-row area	"	1.09	-

Worm Populations

Worm population levels are shown in Figure 4.1 with the minimum tillage areas all showing the benefits of organic mulches and no cultivation to worm health and productivity. This increase in worm populations would also be reflected in populations of other beneficial insects and soil microbes.

Figure 4.1: Worm populations present in conventional and minimum till systems.



Soil Aggregate Stability

Soil structural stability has returned to native soil condition under the minimum tillage regime with aggregates showing high level of stability relative to aggregates sampled from plastic treatment (Figure 4.2 & 4.3). Soil stability has improved due to the improved levels of organic carbon and organic activity within the soil. This improvement in soil aggregate stability has resulted in improved infiltration and low soil erosion levels observed during high rainfall events over the length of the experiment.

Figure 4.2: Soil aggregate stability tests.

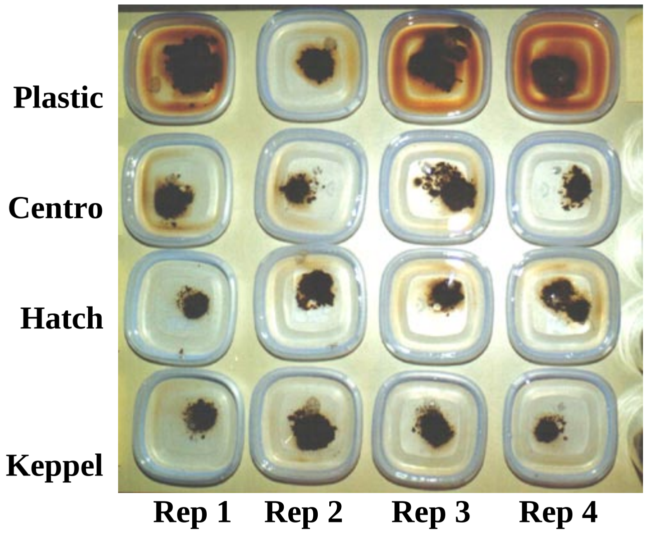
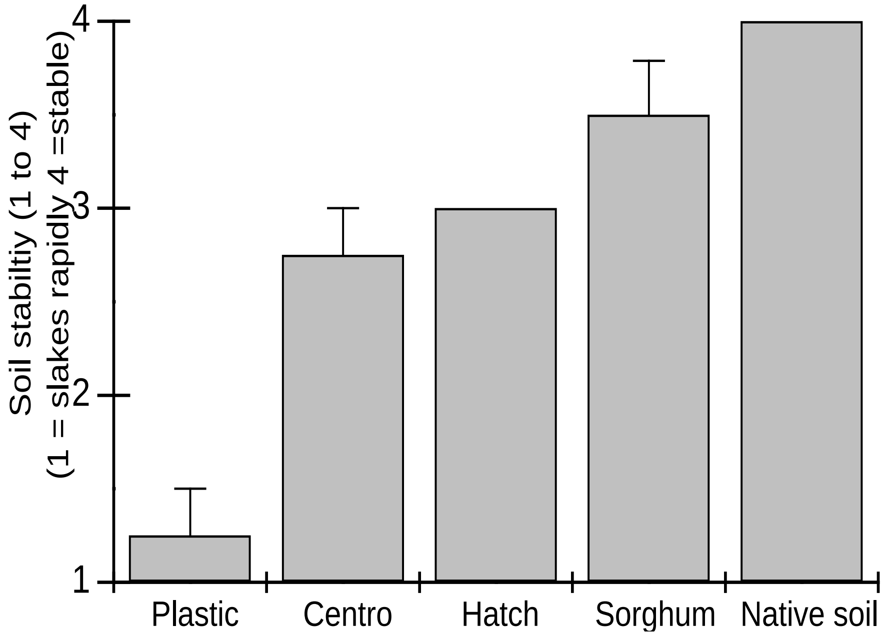


Figure 4.3: Soil Aggregate Stability in conventional and minimum till systems.



Soil Bulk Density

Samples were taken to determine the difference in soil compaction under the permanent bed system when compared to samples from conventional production areas and the native soil. Figure 4.4 shows a comparison between soil taken from permanent beds not cultivated for four years relative to conventional and native soil samples. The low bulk density in the permanent bed soil is the direct result of minimum tillage and the retention of mulch residues over the soil surface increasing organic matter, organic activity thereby improving soil aggregation and structure.

Figure 4.5 shows the benefits of organic mulches to soil bulk density. After two years under cover crops and their mulch residues, all treatments are significantly lower than the plastic control with the Indian Bluegrass varieties producing the lowest level of soil compaction of the five mulch types.

Figure 4.4: **Soil bulk density levels under different mulch types**

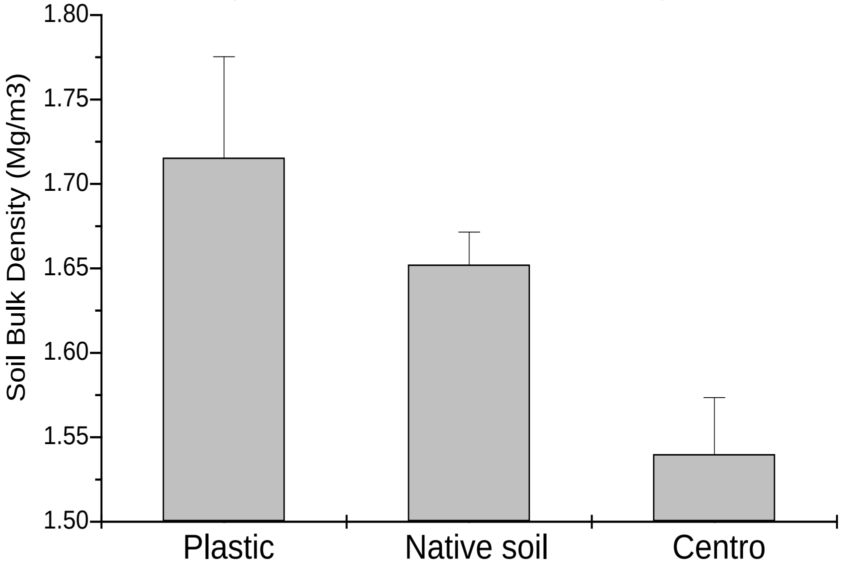
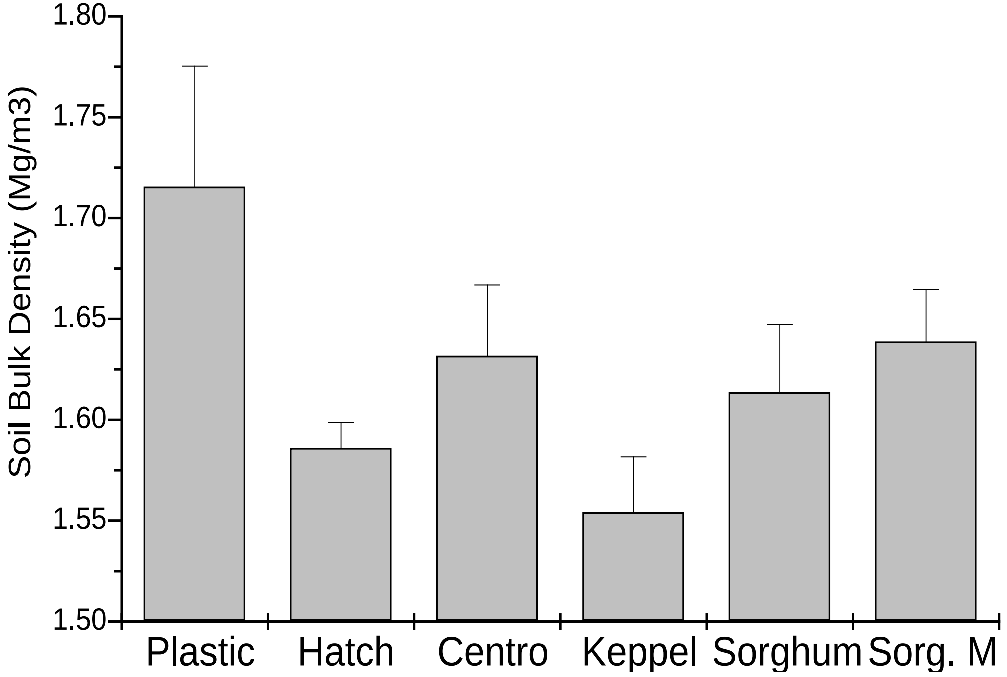


Figure 4.5: **Comparison of soil bulk density levels after two years under different organic mulch types.**



Nematode Assessment

Initial experiments conducted by staff from the Queensland Department of Primary Industries, Bundaberg screened *Centrosema pubescens* cv. Cavalcade and found that it was not a good host for *Meloidogyne javanica*. However, results presented in table 4.3 of experiments undertaken on the sandy soil of the Road Block experiment area indicated that *Centrosema* is a host for root knot nematodes when grown on sandy soils. The species present in the Road Block was identified using a DNA technique and found to be similar to *Meloidogyne javanica* but not identical.

Table 4.3: Nematode Counts in Permanent Beds

	Nematode counts (Nematodes / 200 mL soil)			
Cover crop	Root knot	Lesion	Spiral	Stubby
Sandy soil - Centro	1800	0	0	0
Sandy soil - Centro (badly affected area)	7900	0	0	0
Clay soil - Centro	0	40	0	0
Control - Sorghum	3	360	5	19

Soil Microbial Assessment

The results presented below are from an assessment conducted by Dr Graeme Stirling. Samples were taken from areas of permanent beds that had been established for 4 years and compared to soil that had been farmed by conventional methods of frequent cultivation, and plastic mulch for about 6 years.

Two fields, permanent bed block H2 (planted 31 July) and standard block H4L (planted in early August) were sampled in late July 2000. Further samples were collected by Graham Stirling on 31 October, when the crop was 3 months old. Samples were collected at depths of 10 and 20 cm.

Various parameters that indicate the biological status of the soil were measured and results are presented in Tables 4.4 and 4.5.

Table 4.4: Pre-Plant Samples (August 2000)

	Permanent (H2)		Standard (H4L)	
	10 cm	**20 cm**	**10 cm**	**20 cm**
Culturable micro-organisms (log cfu/g soil)				
Total bacteria	7.24	7.81	7.39	6.93
Gram positive bacteria	6.93	6.67	6.39	6.39
Fluorescent pseudomonads	5.60	4.81	3.81	4.2
Actinomycetes	6.85	5.93	7.43	6.54
Total fungi	5.39	4.85	4.86	4.20
Microbial activity (µg FDA hydrolysed/g/min)	0.348	0.253	0.193	0.312
Free-living nematodes (numbers/200 ml soil)				
Fungal feeding nematodes	940	840	550	846
Bacterial feeding nematodes	1340	2040	550	1800
Omnivorous nematodes	88	20	0	9

Table 4.5: Post-Plant Samples (October 2000)

	Permanent (H2)		Standard (H4L)	
	10 cm	**20 cm**	**10 cm**	**20 cm**
Culturable micro-organisms (log cfu/g soil)				
Total bacteria	8.30	7.39	7.39	7.22
Gram positive bacteria	7.30	5.93	6.74	7.22
Fluorescent pseudomonads	5.30	5.08	4.93	4.85
Actinomycetes	6.39	6.59	6.39	6.74
Total fungi	5.22	5.53	5.36	5.04
Microbial activity (µg FDA hydrolysed/g/min)	0.339	0.268	0.276	0.259
Free-living nematodes (numbers/200 ml soil)				
Fungal feeding nematodes	200	150	160	240
Bacterial feeding nematodes	860	760	400	450
Omnivorous nematodes	7	2	6	0

Interpretation

1. These soils had more free-living nematodes and a higher microbial activity than most other tomato-growing soils in Bowen and Bundaberg. I suspect this is due to the fact that both fields have only been cultivated for about five years and large amounts of organic matter (in the form of green manure) are returned to the soil each year.

2. Results of the pre-plant samples showed that biological activity in the upper 10 cm of soil from the standard block was lower than in the permanent bed. This is evidenced by the lower microbial activity, lower numbers of free living nematodes and a reduction in the populations of fluorescent pseudomonads in this zone. These effects are possibly due to the detrimental effects of cultivation when the field was being prepared for planting. The low numbers of omnivorous nematodes in the standard block may also be due to cultivation. These large nematodes are usually killed when soil is cultivated.

3. Samples taken from the upper 10 cm of the permanent bed when the crop was 3 months old showed that there were more gram positive bacteria, total bacteria, fluorescent pseudomonads and bacterial-feeding nematodes, and greater microbial activity than in the upper 10 cm of the standard block. These differences were not apparent at 20 cm.

4. Overall, these results suggest that the soil in the permanent bed has a better microbial status than the standard block, particularly in the upper 10 cm of soil.

Soil Temperature

Soil temperatures were recorded in two separate experiments over the duration of the project, once in 1998 and again in 2000. Temperature surveys were undertaken to quantify the differences in temperature between plastic mulch and organic mulch. It was initially thought that temperatures under the mulch would be more beneficial to plant growth than the very hot temperatures under the plastic mulch, however many results show that temperatures under the organic mulch are lower than the optimal level for tomato root development and activity, potentially restricting the plants productivity.

Temperatures were taken using a hand-held digital thermometer with a temperature probe inserted to a depth of 10cm below the soil surface under a range of mulch types. Temperatures were taken at four sites in each mulch type and the average taken.

The results presented in Figures 4.6 and 4.7 show that soil temperature were, on average, 4-5°C less than under black plastic in 1998 and 5-7°C less in 2000. Soil temperatures were frequently below the ideal temperature for plant production, under organic mulches in both surveys.

Figure 4.6: Soil Temperature survey, July-August 1998.

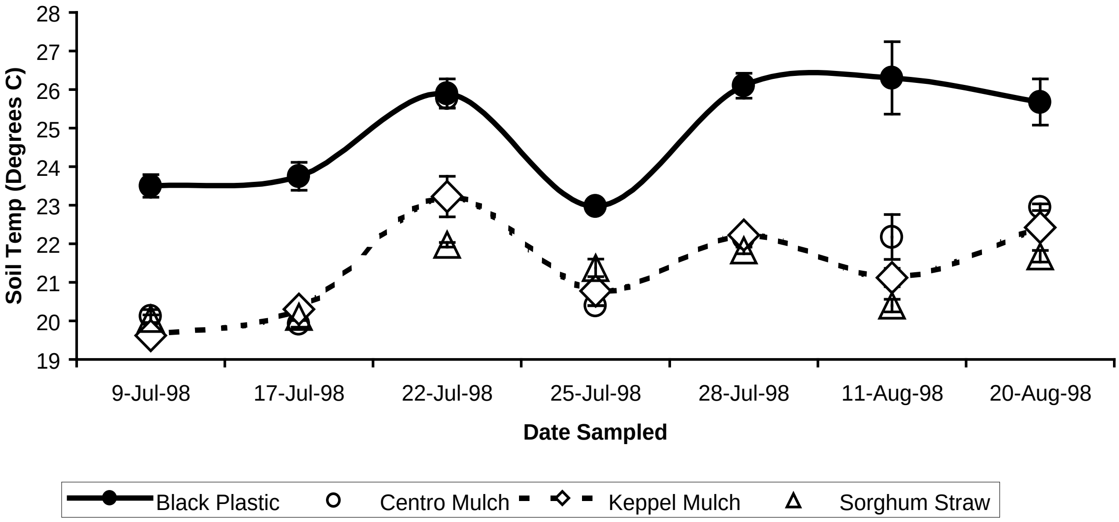
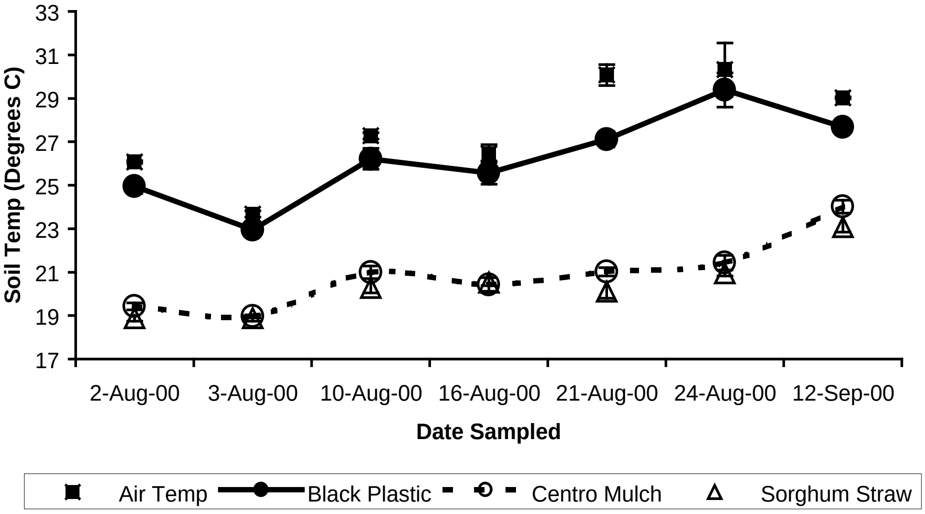


Figure 4.7: Soil Temperature survey, August-September 2000.



Note: Error bars are mainly obscured by the data points.

Discussion

All changes in soil quality are a result of reducing tillage and providing an organic mulch covering the soil. Whilst organic carbon has remained stable under the minimum tillage regime, the act of leaving organic residues on the soil surface to breakdown has encouraged soil biological activity, which has inturn lead to improved soil aggregation and lower soil bulk density.

SECTION 5: Allelopathy and Nutrient Drawdown Experiments

Introduction

Two experiments were conducted to determine the extent of nutrient drawdown and allelopathy as a result of the presence of organic mulches on the soil surface in the permanent bed system. Nutrient drawdown occurs when soil fungi and bacteria utilise nutrients present in the soil to fuel the breakdown of organic material, resulting in lower levels of soluble nitrogen within the soil. Allelopathy occurs when one species of plant releases compounds which suppress the growth of other plants.

The first experiment determined plant nutrient levels in crops grown under organic mulch relative to crops grown unde plastic mulch to determine the level of nutrient drawdown resulting from the decomposition of the cover crop residues. The second of these experiments was undertaken to determine minimum time required between spraying cover crops to alleviate allelopathic effects on crop development.

Methods

Nutrient Drawdown Experiment

Five mulch types: Plastic, Centro, Hatch, Keppel and Sorghum straw were established on the permanent beds and planted with Capsicums. Leaf samples were taken at flowering and analysed for nitrogen, phosphorus and potassium levels.

Allelopathy Experiment

Six different mulches were established on permanent beds. Cover crops grown in situ were sprayed with herbicide and left for a period of one month. Capsicum seedlings (cv. Merlin) were then transplanted at three-week intervals in five metre long plots, and each treatment replicated four times. Fruit yields were recorded by harvesting at regular intervals and crop nutritional status monitored using leaf and soil analysis at flowering stage.

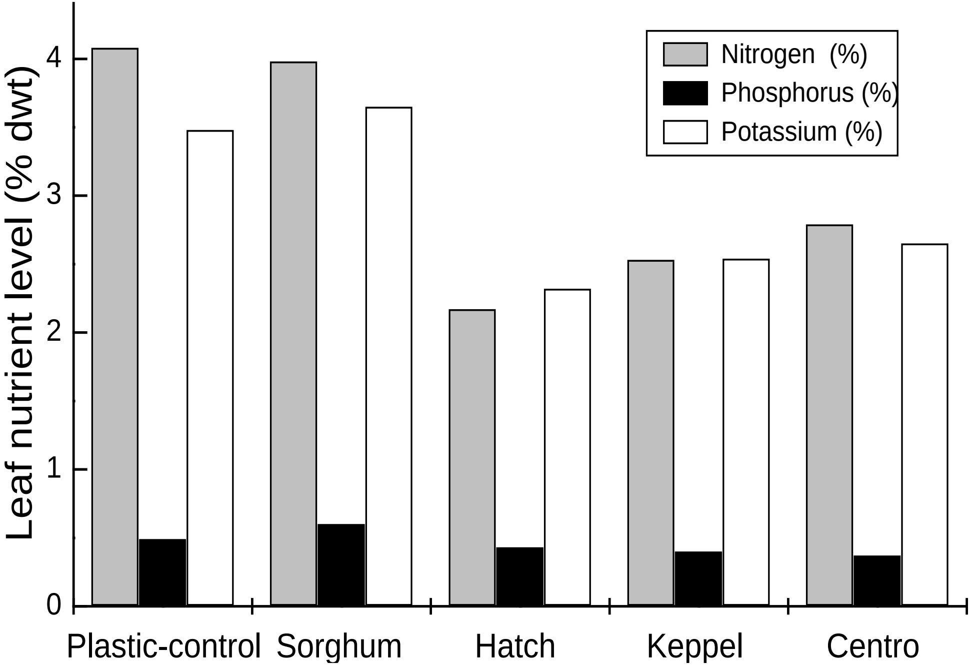
The following mulches were experimentled: Plastic (control), Jumbo sorghum, Centro, Hatch, Sorghum mulch (grown off site and spread on beds), and Keppel

Results

Nutrient Drawdown Experiment

Capsicums grown under in-situ cover crop mulches showed significantly lower levels of Nitrogen and Potassium and slightly lower levels of Phosphorus than plastic and sorghum mulch treatments as shown in Figure 5.1. The high nutrient levels in the sorghum treatment relative to the other organic mulches suggest that nutrient drawdown from organic breakdown is minimal, however the use of nutrients by cover crops has a significant effect on the level of soil nutrients available to the commercial crop.

Figure 5.1: Leaf Nutrient Levels in Capsicums



Allelopathy Experiment

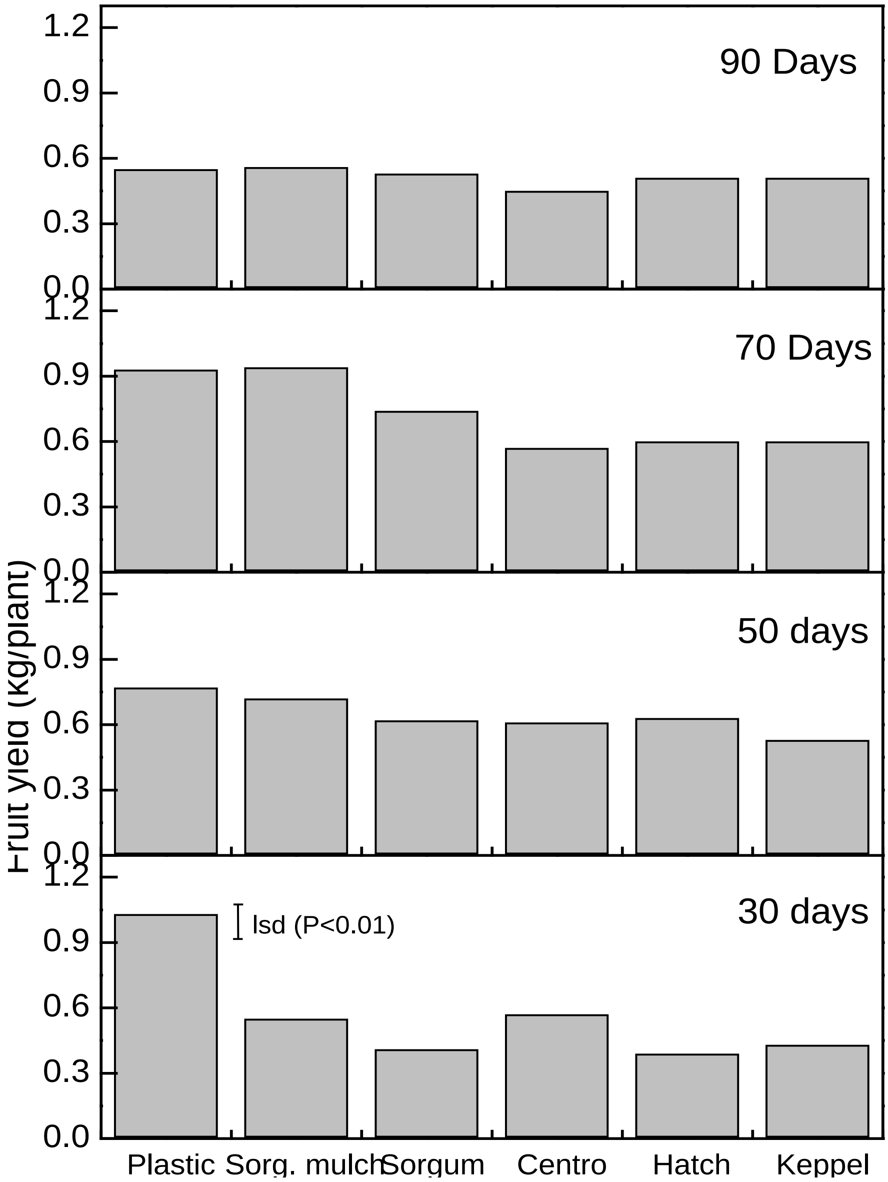
Following the results of the nutrient drawdown experiment, the allelopathy experiment was conducted to isolate allelopathic effects by applying additional NPK fertiliser through the subsurface irrigation ensuring adequate nutrition of the experiment crops. Results shown in Figure 5.2 indicates that sorghum, Hatch and Keppel suppress the growth of capsicums compared to applied sorgmun mulch and Centro at 30 days after killing the cover crops. There are no allelopathic effects attributable to Centro at any time. The higher yields of plastic at 30 days after killing are due to faster plant development. From 50 days onward, allelopathic effects are minimal.

At 70 days after spraying plastic mulch and sorghum mulch yield more fruit than plants grown in mulch residues. This may be due to climatic effects at planting, since at 50 and 90 days after spraying, there is no significant effect of mulch type on fruit yield.

Leaf tissue tests taken show that at 30 days after spraying, when there was growth suppression in all but the plastic treatment, there was no difference in leaf N, P or K levels. Similarly, there were no differences between leaf nutrient levels at 90 days after spraying where yields between treatments were also the same. All leaf nutrient levels were within the “normal” range of nutrition at flowering.

The results indicate that nutrient deficiency (nutrient drawdown) is not the cause of yield differences observed in capsicums planted into cover crop residues 30 days after spraying.

Figure 5.2: Effects of post spraying interval on capsicum yields for various mulches



Discussion

To ensure nutrient drawdown by the cover crop does not effect the vigour and yield of the following crop, additional fertiliser should be applied as part of the basal application, or preferably, through subsurface trickle just prior to establishment of the commercial crop.

Allelopathic effects of subsequent crops can b avoided by allowing the dead cover crop a period of 50 days after spraying to allow allelopathic chemicals to breakdown in the soil in the case of sorghum, Hatch or Keppel.

There does not appear to be an allelopathy problem with Centro. Data from NSW trials suggests there are no allelopathy problems with wheat, barley, oats or rye but confirm allelopathic effects from sorghum.

Allelopathy can also be avoided by selecting cover crop / commercial crop rotations that do not combine allelopathic producing cover crops with sensitive commercial crops such as Capsicums (Abdul-Baki, pers. comm.).

SECTION 6: Crop Evaluation Experiments

Introduction

The objective of the crop experiment was to determine how various horticultural crops would perform when grown under the permanent bed system. The experiment area was sown to Centro in early February and sprayed off in early May, the mulch cover for the experiment area was thin, however the experiment was continued with attention paid to controlling weeds by hand and with knockdown herbicides.

Methods

The vegetable crops experimented included Butternut Pumpkin, Eggfruit, Ground Tomato, Rockmelon, Zucchini, and Honeydew. The crops were planted as seedlings with the exception of Zucchini, which was grown from seed. The planting dates and varieties used are shown in the table below. Crops were irrigated as required on an individual row basis whilst nutrition and spray regime was the same throughout the experiment.

Planting date, spacings, and varieties used in Crop Experiment.

Crop:	Pumpkin	Eggfruit	Tomato	Rockmelon	Zucchini	Honeydew
Variety:	Butternut	"Black Pearl"	"Guardian"	"Eastern Star"	"Panther"	"DewCrisp"
Spacing:	100cm	60cm	50cm	50cm	50cm	50cm
Planting Date:	11/08/00	18/07/00	18/07/00	18/08/00	5/09/00	18/08/00

Yields were determined by harvesting four 5m plots throughout the experiment area (n=4). The mean yield and standard error of each treatment was then calculated.

Results

All crops grew well on organic mulch without significant disease problems. Fruit quality and yield were similar to conventionally-grown crops with the exception of the ground tomato and Honeydew crops. Yield data taken from the experiment is shown in the table below. Photographs taken during crop development are shown in Figures 6.1a-f.

Average yields

Crop	Variety	Yield (kg/ha)	SE	Number of harvests
Eggfruit	Black Pearl	47.6	2.5	4
Tomato	Guardian	30.8	0.9	2
Rockmelon	Eastern Star	10.8	0.13	1
Zucchini	Panther	13.8	1.0	9

Figures 6.1 a-f: Crops produced during the crop evaluation experiment.

a) Butternut Pumpkin

b) Egg Plant “Black Pearl”

c) Tomato “Guardian”

d) Rockmelon “Eastern Star”

e) Zucchini “Panther”

f) Honeydew “Dew Crisp”

Discussion

Potential problems with ground crops marking and transmission of diseases from mulch to fruit eventuated in the tomato and honeydew crops due to the proximity of the fruit to the moist soil surface as a result of the thin mulch cover. Fruit resting on the mulch showed signs of fungal infection in the tomatoes whilst honeydew fruit was marked by brown blemishes on the skin. Marking on the Rockmelon crop was not as severe and in most cases was similar to marking observed in conventional production, Butternut Pumpkin showed little or no marking on the fruit. Eggfruit harvested was of excellent size and colour as were zucchini harvests. A comparison of yields between conventional system and the permanent bed system could not be performed. However the objective of the experiment was to determine if other crops could be grown successfully on the permanent bed system with all crops showing potential, with improvements in management of both cover crop and commercial crop.

SECTION 7: Irrigation Experiment – Bottom Up Irrigation

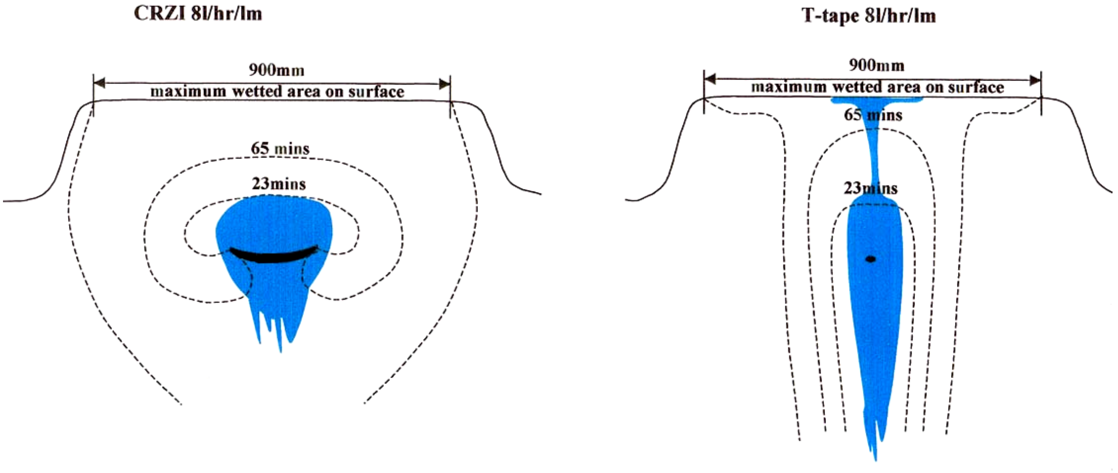
Introduction

A experiment was set up to investigate differences between different forms of sub-surface irrigation. The objective of the irrigation experiment was to evaluate the effectiveness of the CRZI irrigation tape compared to a range of other tapes including the two tapes per bed of Netafim tape used throughout the rest of the permanent bed experiment.

The CRZI product comprises a bottom layer of impervious plastic that is overlain by a layer of geofabric with trickle tube sandwiched between the two layers. The width of the CRZI product used was 300mm. The drip tape within the CRZI product is typically standard trickle tube emitting a volume that is determined through evaluation of soil physical characteristics. The advantages of CRZI determined from previous research (Bottom Up Irrigation, 1999) are:

- produces a wide and uniform wetting pattern (see Figure 7.1),
- reduced water loss to deep percolation,
- reduced damage to soil structure through elimination of tunnelling above drippers, and
- greater overall water use efficiency.

Figure 7.1: Section view of wetting pattern around CRZI and T-Tape in a sandy loam (Bottom Up Irrigation, 1999).



CRZI 8l/hr/lm

T-tape 8l/hr/lm

__Note:__ Beds only received 43% of intended volume due to lack of pressure in supply line

Methods - Experiment 1, 1999

Six forms of sub-surface irrigation were installed, T-tape, Netafim, Pathfinder, Triangle filtration and CRZI at 2 flow rates (high and low). The flow rates were matched at 500 L/100 m with the exception of CRZI, which has a higher application rate for this experiment. In subsequent experiments, the CRZI was irrigated using timers to match the flow rates of other products.

The objective of the experiment was to collect data on soil moisture levels and fruit yield (tomatoes). Soil moisture levels were recorded using an Aquaflex soil moisture sensor buried at 10cm. The Aquaflex records soil moisture along a 2m strip of soil and graphs the mean level of soil moisture along that strip. Aquaflex sensors were buried in the Netafim control treatment and one of the CRZI treatments and the results compared.

Tomato yields could not be measured due to crops being destroyed in accordance with a crop moratorium to prevent whitefly populations building up. However plant biomass was determined prior to crops being destroyed by drying and weighing 4 replicates of 2 plants per treatment.

Results - Experiment 1, 1999

The data shows that plant growth was suppressed in the CRZI treatments, especially the high water treatment (Figure 7.2). The soil water data (Figure 7.3) indicates that soil water levels using CRZI were consistently higher than that for Netafim, which was being used as a control for this experiment.

The likely explanation for CRZI resulting in less crop growth than the other irrigation types was over watering. Data supplied by the manufacturers suggest that CRZI is more efficient in water use, and supplying water a rate similar to trickle tube likely to cause waterlogging (D. Hinton pers. comm.).

Figure 7.2: Tomato growth on various sub-surface irrigation types.

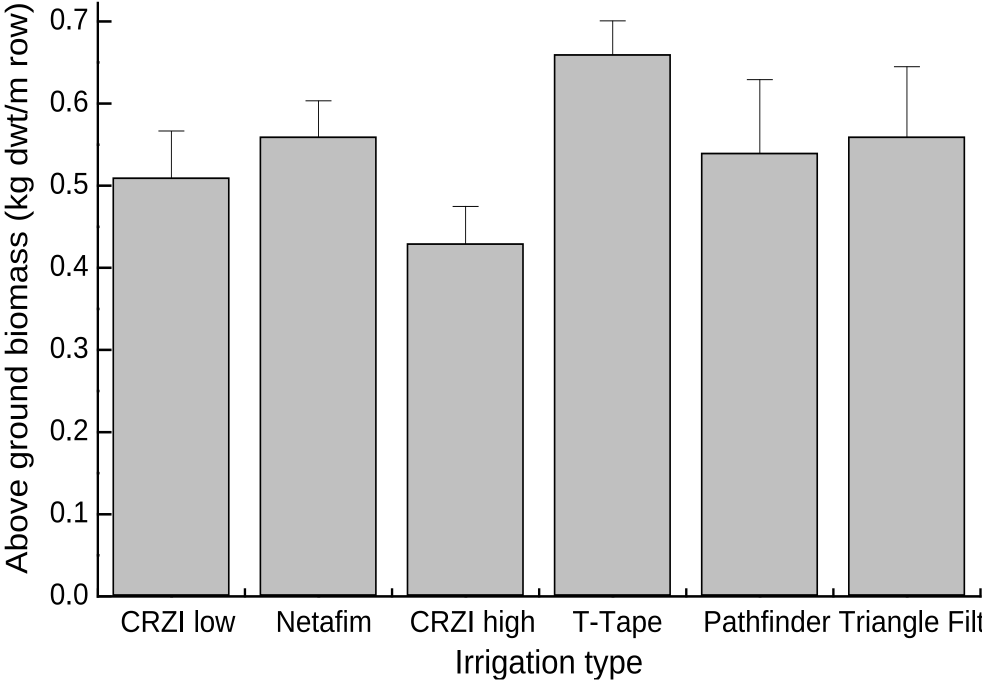
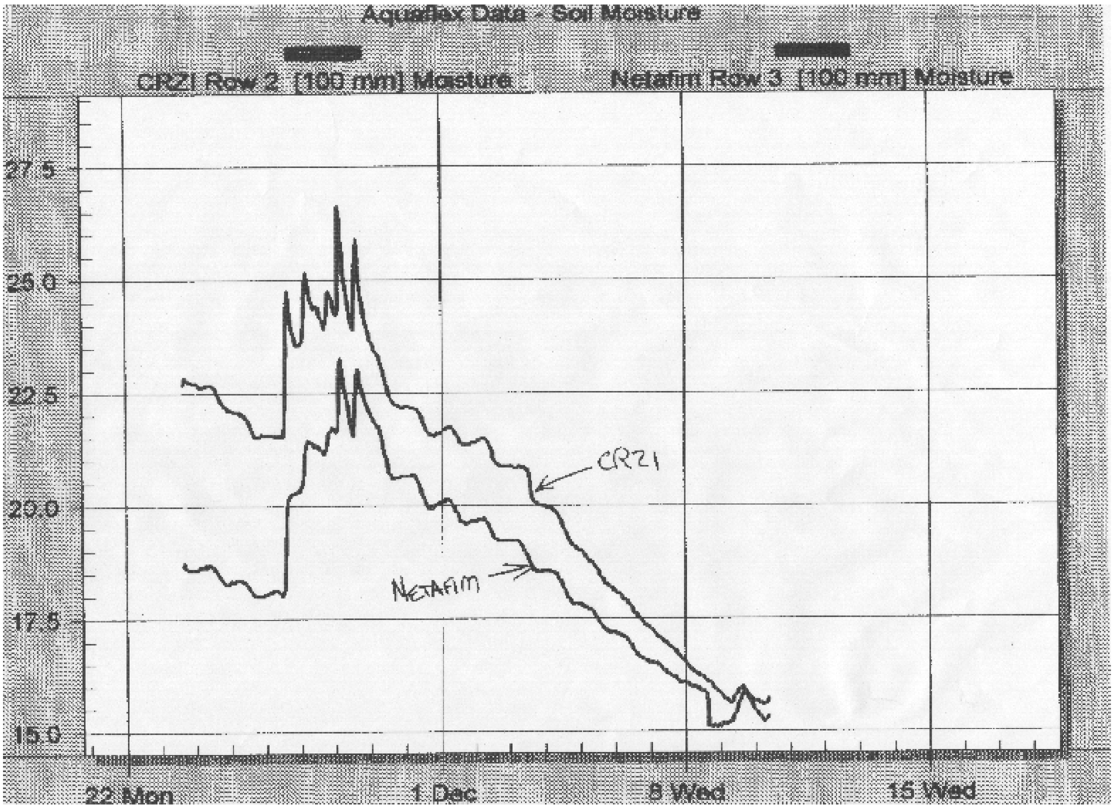


Figure 7.3: Soil moisture levels for CRZI and Netafim (Tomatoes).



Methods - Experiment 2, 2000

The experiment was planted with Capsicum variety “Merlin” at 25cm spacings by hand on 22nd June and tensiometers installed. Taps connected to each irrigation tape in each row of the experiment were used to control the length of time irrigation was required. Irrigation was scheduled at the same time for all treatments using tensiometers and soil inspection to determine when irrigation was required. The length of time required to wet up each row of the experiment was noted and irrigation for that row shut off when the tensiometer reached the desired level, usually 8-10kPa.

Fruit was picked twice from four replicates of 5 metre strips within each row, separated into red and green fruit, counted and the fruit from each colour weighed. Yields were determined by taking the mean of the four replicates in each treatment.

Results - Experiment 2, 2000

Observation of the capsicum plants through the life of the crop showed that bush size was greatest in the single row treatments of Nelson Pathfinder, Triangle Filtration and T-Tape with bushes on the Netafim treatment less vigorous and CRZI treatments less vigorous again.

Results of fruit yield tended to reflect the observations made of plant vigour, however the differences in total yield between the treatments did not show statistical differences in either weight or numbers of green fruit harvested nor weight or numbers of unmarketable fruit. Numbers and weight of red fruit picked did show some statistical differences between the treatments. The Triangle filtration treatment produced significantly higher numbers and greater weight of red fruit than all other treatments. The Nelson Pathfinder and T-Tape treatments produced statistically significantly higher yields of red fruit to all other treatments with the exception of one row of CRZI tape (5 litres per metre per minute), with the Netafim and the two CRZI treatments showing no significant differences.

Figure 7.3: Total harvest figures for Capsicum "Merlin"

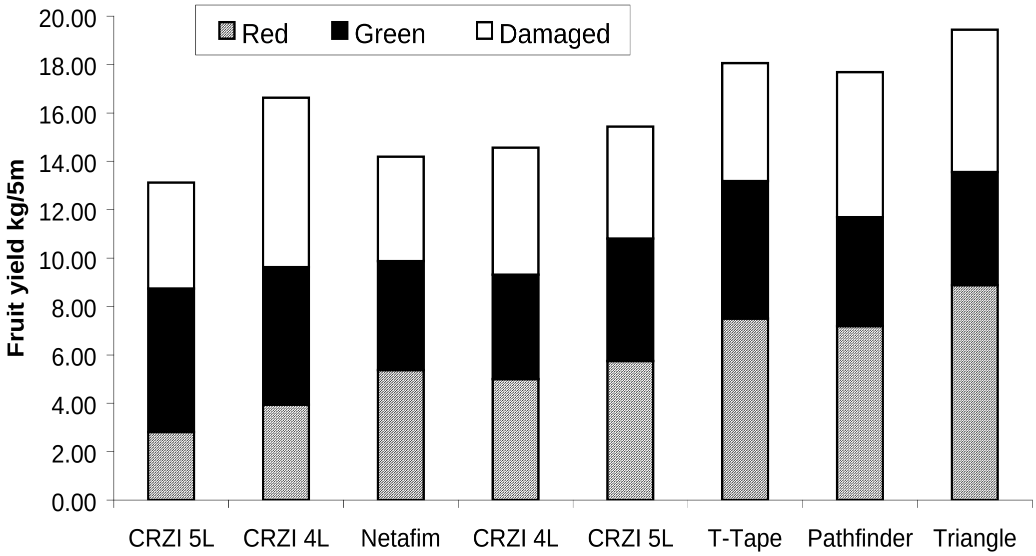


Figure 7.4: Capsicum production during the irrigation experiment.

The difference between the treatments was amount of water required wetting up the profile sufficiently. The shorter the irrigation time required and the lower the output of the trickle tape the greater the efficiency of the tape in question. To this end the CRZI, T-Tape and Nelson Pathfinder irrigation used less water overall than the standard double row of Netafim and the Triangle Filtration treatments.

	Netafim	CRZI 4L	CRZI 5L	T-Tape	Pathfinder	Triangle
Total Hours	103.75	81.25	81.25	81.25	81.25	81.25
Rate per Hour	7.8 litres	4 litres	5 litres	5 litres	5.1 litres	7.95 litres
Total Volume	809.3 l/m	325.0 l/m	406.3 l/m	406.3 l/m	414.4 l/m	645.9 l/m
% of Netafim	100	40.2	50.2	50.2	51.2	79.8

The lower yields and plant vigour associated with the CRZI could be the result of over watering in the early stages of growth and a lack of water movement, and hence root development, below the level of the irrigation tape.

Discussion

The main problem with the CRZI irrigation tape is the width of its impermeable layer. Whilst this layer is important to the wetting pattern achieved, once soil moisture is beyond field capacity, water cannot readily drain away from the surface through the soil profile, resulting in a waterlogged rootzone.

The model of CRZI used in these experiments has since been modified to a much narrower strip. This new design will help to minimise the damage to plants and plant roots done by over watering using the CRZI. Over watering in the experiments conducted damaged the plants as a result of water not being able to drain through the soil profile. The new narrow model of CRZI would enable more water to drain through the soil due to the impermeable layer within the CRZI being half the width of that used in the experiments outlined above.

The benefit of CRZI in a minimum tillage system is that the tape can be left permanently in the soil for many years without being damaged by crickets or other fauna within the soil. The CRZI also produces an even, wide wetting pattern over the entire bed ensuring even cover crop germination and plant development.

SECTION 8: Herbicide Experiments - Bowen

Introduction

An important factor in the management of the minimum tillage system is the ability to readily kill cover crops within a known time frame to enable commercial crops to be planted in accordance with the farm schedule. The killing of the cover crops grown in Bowen, particularly Centro, was challenging for researchers and as a result a small-scale herbicide experiment was conducted as well as evaluating herbicides on a commercial scale.

Herbicide Experiment – Methods

The herbicide experiment was conducted on Centro planted in the AHR experiment area to determine the performance of Spray Seed®, Kamba M®, Basta® at 1.5 times the label rate, and higher rates of Glyphosate based herbicides in killing off the Centro cover crop. Herbicide treatments are summarised in Table 8.1. Each herbicide was applied over plots 10 metres in length over 5 rows using a conventional high volume spray boom (360L.ha-1).

Table 8.1: Treatments used in the herbicide experiment.

Herbicide Used	Rate	Active Ingredient
Basta®	7.5L.ha^{-1}	Glufosinate-Ammonium
Kamba M® + Smart 450®	5.5L.ha^{-1} 3.5L.ha^{-1}	Dicamba & MCPA Glyphosate
Smart 450®	7.2L.ha^{-1}	Glyphosate
Spray Seed®	3.4L.ha^{-1}	Paraquat

An additional test using Metham was conducted over a row length next to the herbicide experiment using a rate of 400L.ha^{-1}

Herbicide Experiment – Results

The experiment was inconclusive as all herbicides did an excellent job of killing the cover crop on that particular day of spraying (see table 8.2), with the exception of Spray Seed, which killed Centro well but did not kill grass weeds that had grown within the cover crop. The experiment using Metham to kill off the cover crop was unsuccessful due to too low a rate of Metham being used. The sustainability of the use of Metham is also in question.

Table 8.2: Results from the Herbicide Experiment.

Treatment	Effect
Metham	Uneven Kill, ~60% of material still green.
Basta ®	Good Kill
Smart 450	Good Kill
Kamba M + Smart 450	Good Kill, some green stems.
Spray Seed ®	Good Kill of Centro. Some weeds, particularly grasses, untouched.

Herbicide Evaluation

A range of herbicides used to kill the cover crop was evaluated throughout the project on a commercial scale. A summary of the chemicals used is shown in table 8.3.

Table 8.3 Chemicals used throughout the project.

Chemical	Active Ingredient
Roundup 360®	Glyphosate
Starane 200 ®	Fluroxypyr
Basta®	Glufosinate-Ammonium
Fusilade®	Fluazifop - P

Herbicide Evaluation – Results 1999

Chemicals Used: Glyphosate, Glyphosate + Starane®, Basta®, Fusilade®

Results: In Centro cover crops, both Glyphosate alone and in combination with Starane® produced inconsistent results with little difference between the two chemical mixtures. Basta was used only as a follow up treatment after areas sprayed with Glyphosate or Glyphosate/Starane® did not achieve 100% kill. Basta® produced reliable kill in these circumstances. In grass cover crops, Fusilade® produced an excellent kill, however if cover crop stands contain populations of broadleaf weeds the use of Fusilade® alone will not kill these weeds, and a follow up treatment would be required.

Herbicide Evaluation – Results 2000

Chemicals Used: Glyphosate, Glyphosate + Starane®, Glyphosate + Starane® + Urea, Basta®

Results: Glyphosate alone produced a slow kill of the Centro cover crop eventually resulting in a 95% kill. Glyphosate plus Starane® produced a faster but less effective kill, around 80% whilst Glyphosate, Starane® and Urea produced a 40% kill on one day (see Figure 8.1) and a 100% kill four days later. Basta® when used to clean up areas of poor kill produced a complete kill on all areas whilst as the sole treatment, produced a 99% kill with some growth emerging from under the mulch layer.

Figure 8.1: Comparison of Glyphosate + Starane® + Urea (left) and Glyphosate + Starane® (right).

The primary herbicide used on the commercial blocks was a mix of Roundup 360® at 6 litres per hectare and 0.5 litres per hectare of Starane® whilst on hydrant 1L and the area on hydrant 23L the above mix plus Urea was used. The kill varied, the kill on hydrant 1L was poor (around 60%) whilst the same mix a few days later on hydrant 23L produced an excellent kill requiring no further treatment. The use of Roundup 360® and Starane® without urea resulted in a reasonably poor kill (80%) on hydrants 1R and 2, however when used on regrowth on the previously sprayed (31st March) areas of hydrant 23L an excellent kill was the result.

A follow up treatment of 5 litres per hectare of Basta® was used on all areas with less than 100% kill; this was the final application of herbicide to the cover crop. The inconsistency of the chemicals used continues to be a problem, ideally the management of the cover crop should be simple and consistent, a herbicide with consistent 100% kill would enable a grower to plan his activities with greater ease and keep the use of herbicides to an absolute minimum.

Herbicide Evaluation – Results 2001

C**hemicals used**: Dual Salt Glyphosate, Basta®

Results: The dual salt glyphosate produced the poorest kill achieved during the experiment so far on both the Centro and Indian Bluegrass cover crops. Basta® again produced reliable clean up on the Centro covers but was not tested on Bluegrass as it typically does not perform well on grasses.

Discussion

As chemical killing of the cover crop has given inconsistent results, non-chemical alternatives are also being considered. Rolling of the cover crop works well in US minimum tillage experiments where annual legumes and cereals can be used as cover crops. Current non-chemical technologies such as flame, steam or hot water; cannot effectively deal with the high biomass produced by the cover crop species used in North Queensland and hence are currently not commercially viable for this system.

SECTION 9: Technology Transfer

1. Sustainable Vegetable Production Field Day, Euri Gold Farms, Bowen, 10th October 2000

The objective of the “Sustainable Vegetable Production Field Day” was to demonstrate the permanent bed system developed by Applied Horticultural Research and Lionel Williams of Euri Gold Farms to vegetable growers in North Queensland, in particular the Bowen and Gumlu Districts. On display was a total of 6.2 hectares of commercial trellised tomato crop consisting of two Roma tomato varieties and one round tomato variety, as well as 0.2 hectares of small experiment areas demonstrating a range of cucurbits, capsicum and egg-fruit all growing in beds covered with organic mulch grown in situ which had not been cultivated for a minimum of four years.

The program commenced with a welcome and introduction to the project by Dr. Gordon Rogers of Applied Horticultural Research who outlined the objectives of the project and the program for the afternoon. Following on from Dr. Rogers, Lionel Williams of Euri Gold Farms discussed how the project had come about, how the system had developed and the practical benefits of minimum tillage, permanent sub-surface irrigation and controlled traffic. Mr. Williams also spoke candidly about the successes and problems of the project to date including problems of weed control and higher irrigation requirements of the crop grown with organic mulch. The formal aspect of the program was concluded with Stuart Little of Applied Horticultural Research giving a brief outline of the benefits to soil organic matter and subsequent improvements in soil physical properties under the minimum tillage system.

The group then split into three groups that rotated between three stations set up throughout the site. Steve Silcock of Applied Horticultural Research and Lionel Williams demonstrated the improved soil physical properties and discussed in greater detail the management requirements of the system in one of the commercial tomato blocks. Stuart Little discussed the small crop experiments of Capsicum, Rockmelon, Honeydew, Egg Fruit, Butternut Pumpkin, Zucchini and ground Tomatoes as well as a experiment of different irrigation tapes, in particular CRZI irrigation tape supplied by Bottom Up Irrigation. The final station demonstrated another commercial planting of trellised tomatoes irrigated using Nelson “Pathfinder” irrigation tape connected to a sub-surface flushing manifold system used to regularly flush trickle tape, which was discussed by Jamie Pickford of Nelson Australia and Dr. Gordon Rogers.

Once the rotation was complete, growers were invited to afternoon tea and drinks and a chance to examine machinery used in the minimum tillage system and to further discuss the project informally with the Applied Horticultural Research representatives, Jamie Pickford and Lionel Williams.

Growers were asked to leave their details with Applied Horticultural Research to enable further information transfer as the project progresses. Attendees included growers from Tully; resellers from Ayr and Bowen; consultants from the local area; seed company representatives; and local vegetable producers from Bowen and Gumlu. Growers who had left their details were contacted recently and asked their impressions of the project with mostly positive responses. A total of 56 people attended the day.

2. Grower Meetings

(i) Growing For Profit, Gympie, November 15th 2000

Applied Horticultural Research (AHR) mounted a display at the “Growing for Profit” day organised by QFVG. Key features of the vegetable growing system were presented to growers and the advantages explained using posters, a PowerPoint presentation and direct discussions with growers.

The conference organisers, The Big Event Company, provided the following feedback regarding the day:

> *We have been working with the Rural Extension Centre on the evaluation. There were some really good positive comments from growers about the topics discussed and the information passed on by each contributor. Overall, the comments judge the event as a success - and Noel Harvey has received some very good feedback from growers. The evaluation shows that around 200 growers attended and felt that it was well worth their time and effort.*

A number of contacts were made on the day including growers implementing or considering minimum tillage in the Gympie, Murgon, Bundaberg, and Gatton regions of South East Queensland.

(ii) Gympie Growing For Profit 2 and Queensland Extension, 4th September to 14th September 2001

Tuesday 4th September

Addressed a group of 20 growers and industry personnel as a part of "Your R&D levy at Work" session of the Laidley Growing for Profit 2 workshop. Questions arose regarding the loss of production occurring during the cover crop stage of the cycle.

Thursday 6th September

Toured the Miandetta Farms enterprise with focus on Asparagus production for the domestic and export market with John Murphy the Export Manager for Miandetta Fresh Foods. Following a tour of the farm and packing facility conducted an informal chat with John Murphy and Ian Nielson managing director of Miandetta farms.

In the afternoon a group of 14 growers and industry personnel attended the Stanthorpe session of Growing for Profit 2 workshop series. Once again a presentation was made outlining the research. Questions were predominantly regarding further details of how the system worked.

Friday 7th September

The morning was spent discussing permanent beds with QFVG Chairman and producer Paul Ziebarth on his property at Laidley. Paul has a system of semi-permanent beds with 2m centres in bays of 12 with a 3m roadway between each bay. Tram tracks will be kept consistent through the use of precision farming technology. Two lines of CRZI 1m apart per bed will supply irrigation.

Saturday 8th September

Visited Dennis Ward's property at Mondure (near Murgon) and looked at the areas where he would like to experiment the permanent bed system. One site is scheduled for zucchinis after Christmas, Dennis would like to sow millet and spray/roll it and direct seed zucchini through the mulch with trickle tape layed on top of the mulch. In the evening the presentation was made to the Mondure/Muurgon growers. 8 growers attended with 2 apologies, the presentation was well accepted with a number of questions and suggestions on a wide range of issues.

Monday 10th September

Attended and spoke to a meeting of the Rockhampton Fruit and Vegetable Growers Association, 8 growers attended with 2 apologies as well as 3 organic producers from Yeppoon.

Tuesday 11th September

In the afternoon a group of 20 growers and industry personnel attended the Bundaberg session of Growing for Profit 2 workshop series. Once again a presentation was made outlining the research. Questions included practical aspects of the system such as bed forming and bed dimensions, the level of rockmelon marking in the vegetable experiment, the use of soil fumigants, centro potential in Bundaberg, and the potential for use of pre-emergent herbicides along the plant row especially with cutting type planters.

Thursday 13th September

A total of 21 growers attended the first day of Growing for Profit in Gympie with 3 growers attending especially to hear the presentation. Questions focussed on the practical aspects of the system such as how the cover crop was sown, and how the beds were formed. Following the presentation Bob Euston showed myself and John Muir of Barung Landcare around his property. Bob uses controlled traffic and organic mulches of millet. Millet is grown on the beds and when finished, beans are planted through the standing residues and the residues then mulched.

Friday 14th September

Visited the farm of organic growers Andrew Monk and Janice Maybin to discuss the permanent bed project, they indicated an strong interest in experiments should more land become available to them in the future.

(iii) Sweet Corn IPM Meeting – Cowra, 16th October 2001

Through contact with NSW IDO Alison Anderson, an invitation for an AHR representative to address the Cowra Sweet corn meeting regarding the permanent bed project was accepted. The Cowra group contained not only sweet corn growers, but growers of a range of horticultural crops. Growers were receptive of the idea and posed a number of questions regarding the finer detail of the system. The use of corn residues as a mulch source, as used by Steve Groff in the US was also discussed.

3. Horticultural Expos

(i) North Queensland Field Days - Ayr Research Station, 10th-11th September 1999.

AHR set up a display and manned it for both days. The display included samples of Keppel, Centro and Sorghum Mulch as well as a number of posters outlining research findings.

(ii) "Expo 16" – Gatton Research Station, 17-18th May 2000

Samples of soil from conventional and permanent bed production were shown and their differing aggregate stability demonstrated to many growers. Samples of both living and dead Centro mulch were also on display. Dr. Gordon Rogers of AHR also gave presentations discussing the permanent bed project in the main tenmt on each day of the expo. There were approximately 200 visitors to the site, including many large growers.
Key contacts made during the 2 days included:

Shane Gisford – Hort. Consultant
John Muir – Farmcare QDPI
Shawna Dewhurst and Noel Harvey (QFVG)
Fergus Roberts – Melon grower Chinchilla
Geoff Tullberg – UQ Gatton
Ashley Sean NSW Agriculture
Eric Hollinger – Sustainable systems (UWSH)

Dr. Rogers was also interviewed by ABC radio during the expo.

(iii) "Sydney Basin Vegetable Expo" University of Western Sydney – Hawkesbury, 11th & 12th May 2001

Applied Horticultural Research occupied a site at the inaugural Sydney Basin Vegetable Expo displaying posters, equipment and information hanouts regarding the permanent bed project. Stuart Little was onsite to discuss the project whilst Dr. Godon Rogers gave a short presentation to visitors in the Horticulture Australia information centre. Over 50 visitors discussed the project with AHR staff including organic and conventional producers, researchers and industry representatives.

4. Information Mail Outs

A four page glossy pamphlet was produced by AHR to aid in technology transfer. Copies of the pamphlet have been handed out during Growing for Profit 2 and Queensland extension, the Sweet corn IPM meeting, and the Sydney Basin Vegetable Expo. Pamphlets have also been forwarded to growers requesting further information on the project. Pamphlets have also been mailed to growers directly through AHR cooperating with the state vegetable industry development officers, with pamphlets being distributed to the following areas:

- 50 copies of the pamphlet were distributed to each of the state vegetable industry development officers in Queensland (Samantha Heritage), NSW (Alison Anderson), Tasmainia (Roger Tyshing), Victoria (Patrick Ulloa) and Western Australia (David Ellement). The pamphlets will be distributed by the IDO's to growers known to have shown interest in sustainable production or innovative farming techniques.

- South Australia – 15 pamphlets to fresh cut growers through Craig Feutrill of the Australian Vegetable Industry Development Group

- The Harvest Company - 30 copies of the pamphlet were also provided to Robert Gray of The Harvest Company for distribution among growers and staff.

5. US No-Till Study Tour

Lionel Williams and Gordon Rogers undertook a trip to the US to investigate no-till vegetable production. During their visit they saw commercial vegetable crops growing successfully in soil that had not been cultivated for 15 years. Cover crops are being used to control weeds and improve soil health. Vegetable crops are planted directly into freshly killed cover crops.

A highlight of the tour was a visit to Cedar Meadows Farm, Holtwood Pennsylvania. The owners of Cedar Meadows, Steve and Cheri Groff, have established a successful no-till farming operation where the farm has not been cultivated for 15 years.

The farm is managed by growing cover crops of rye, oats and hairy vetch. When these cover crops are at the flowering stage, they are killed by rolling (crimping) or chopping, and vegetables are transplanted or direct-seeded straight into the fresh mulch residues. The seed or seedlings are transplanted, usually within hours of rolling the cover crops. There is no delay in the cropping cycle. This system works well for all the vegetable crops except capsicums, where some growth inhibition still occurs. Steve uses a transplanter built by RJ Engineering in Canada to plant his seedlings, and a conventional stubble seeder to plant direct-seeded crops such as sweet corn and soybeans.

In most cases rolling or chopping is enough to kill the cover crops provided they have reached the flowering stage. In some cases, Steve uses low rates of glyphosate a couple of days before rolling. He also uses some post-emergent selective herbicides on tomatoes and sweet corn. “Weeds are generally then suppressed by the organic mulch residues which remain on the soil surface” he said.

The Groff’s grow a range of vegetable crops including fresh-market and processing tomatoes, capsicums, rockmelons, watermelons and sweet corn.

The visit to the Cedar Meadows farm, coincided with Steve Groff’s annual field day on no-till vegetable production. About 500 farmers, scientists and other interested people turned up to see no-till vegetable farming in practice.

The Deputy Secretary of the USDA, Dr Richard Rominger spoke at Steve’s field day and gave his wholehearted support to the sustainable vegetable production work. Also giving talks at the field day were some highly respected members of the scientific community. Prof. Ray Weil, a respected soil scientist from the University of Maryland spent the day in a soil pit, explaining why the soil had benefited from not having been cultivated for 15 years. There were worm holes down to the subsoil, the topsoil was crumbly and friable, and there was no compaction.

Another respected US scientist, Dr Fred Magdoff, director of the USDA Sustainable Agricultural Research and Education (SARE) program, was explaining the benefits of cover cropping and no-till. Dr Magdoff tested the soils on Steve’s farm for compaction, and concluded that the soils were in excellent condition, not compacted despite the lack of cultivation.

USDA Research into No-Till Vegetables

The team from Australia visited the USDA research facility at Beltsville, Maryland. This facility occupies over 4000 hectares and employs over 1000 staff. We met with Dr Aref Abdul-Baki, and Dr John Teasdale, both pioneers in the field of cover crops for use in vegetable cropping.

Dr Baki has experiments in Maryland, California and Florida. The Florida climate is very similar to the Bowen/Burdekin climate. Dr Abdul-Baki said “In Florida you need cover crops adapted to warm climates. Sun Hemp and Velvet bean are both successful, but you need to grow the correct varieties”.

Drs Abdul-Baki and Teasdale have shown they can achieve better yields in crops such as tomatoes using no-till and planting through mulch residues than can be achieved using conventional cultivation and plastic mulch.

6. Industry Development Officers

Through the production of short articles for grower newsletters, mailouts of information, and efforts to present research findings at grower meetings, constant contact has been maintained with Industry Development Officers in Queensland, New South Wales, Victoria, Tasmainia, Western Australia and South Australia. All Industry Development Officers have received copies of the information pamphlet and are aware of the project and its findings.

7. Publications

Articles in Good Fruit and Vegetables

A number of articles have been published in the industry magazine ***Good Fruit and Vegetables*** outlining the progress and practical aspects of the research. These articles were:

1. Rogers, G.S., Little, S.A., Silcock, S.J., Williams, L. (2002) "No-till vegetable production using organic mulches in the dry tropics of Australia" ACTA Horticulturae. **XXVI International Horticultural Congress, Horticulture: Art and Science for Life**, Toronto, Canada, 11th-17th August, 2002

2. **Rogers, G.S. Little, S, and Williams, L.** (2002) Production of muskmelon (*Cucumis melo* L.) using winter cereals as cover crop mulches. **HortScience.** In prep.

3. **Rogers, G.S., Little, S. and Williams. L**. (2002) Changes in soil physical properties under a no tillage tomato production system. **Plant and Soil**. In prep.

4. "Development and Implementation of a Permanent Bed System for Vegetable Production" ***Good Fruit and Vegetables***, in publication (December 2001).

5. **Rogers, G. S., Silcock, S., Little, S., and Williams, L.** (2000). "Integrated system improves vegetable establishment results" ***Good Fruit and Vegetables*** **10(10)** pp 35-36.

6. **Rogers, G and Silcock, S. Williams, L.** (2000) "Experiencing the no-till thrill" ***Good Fruit and Vegetables*** **11(5)** pp.80-81.

7. Rogers, G and Silcock, S. Williams, L. (2000) "Sustainable Permanent Bed Systems for Vegetable Production" ***Good Fruit and Vegetables*** **10(12)** pp. 48-89

8. **Chaloner, D., Williams, L., and Rogers, G.** (1999). "Better bed systems for vegetables" ***Good Fruit and Vegetables*** **9(9)**, pp 48.

Articles in Newsletters and Grower Magazines

Articles have also been published in state based vegetable growers magazines and newsletters. These articles were typically one-page summaries of the research with contact details for Applied Horticultural Research attached, encouraging growers to seek further information. Articles have been placed in the following publications:

1. "A permanent bed for vegetables". **Vegetable Matters**, Issue 3, December 2001.

2. Development of a permanent bed system for tomato production". **Tomato Topics,** December 2001 10(4): p2.

3. ***Western Australian Vegelink***, Issue 8 – September 2001 inside ***WA Grower*** September 2001 Vol. 32 No. 3

4. ***VEGELink NSW***, Issue 1 – September 2001

5. ***Vegetable Matters***, (Victoria) in publication.

6. Articles have also been published in the print media in North Queensland including:

7. "Soil Coverage the key to US no-till success" ***North Queensland Fruit and Vegetable Grower*** August-September 2000. p. 33.

8. "Bowen man keen on environment" ***Rural Bulletin***, Townsville. October 2000. p. 14.

9. "Farmers diversity" ***Rural Bulletin***, Townsville. October 2000. p. 15.

10. "Sustainable Permanent Bed Systems for Vege Production." ***North Queensland Fruit and Vegetable Grower*** May-July 2000. pp. 22-23.

11. "Sustainable permanent bed systems for vegetable production" ***North Queensland Register - Rural Care 99***. 18th March 1999.

12. "Sustainable permanent bed systems for vegetable production" ***Queensland Country Life*** March 1999.

Other Publications and Presentations

1. **Rogers, G. and Chaloner, D.** (1988) "Role for Biofumigants in sustainable vegetable production" ***Biofumigation Update*** No. 7 CSIRO.

2. **Rogers, G.** (1998). "Sustainable permanent bed system for vegetable production." ***HortReport 98.*** Horticultural Research and Development Corporation.

3. **Chaloner, D., Williams, L., and Rogers, G.** (1998). "Pathogen control, weed suppression and permanent vegetable beds using pasture grasses and biofumigant Brassicas." ***Managing Our Future for Innovation, Sustainability, Continuity***. Australian Society of Horticultural Science 4th Australian Conference, Melbourne 14-17th October. p. 29.

4. **Rogers, G., Silcock, S. and Williams, L.** (1999) "Sustainable Permanent Bed System for Vegetable Crops" Presentation at NSW Agriculture on Sustainable Vegetable Production Systems, NSW Agriculture, Narara May 1999.

5. **Rogers, G., Silcock, S. and Williams, L**. (1999) "Sustainable Permanent Bed System for Vegetable Crops" ***Overcoming the disposal of plastic mulch - Meeting of Stakeholders***, QDPI Bundaberg, 14th July 1999

6. **Little, S., Rogers, G., Silcock, S. and Williams, L**. (2001) "Development of a sustainable integrated permanent bed system for vegetable crop production."Australian Society of Horticultural Science, Regional Meeting, Sydney 31st August 2001.

International Communications

1. Rogers, G.S., Little, S.A., Silcock, S.J., Williams, L. (2002) "No-till vegetable production using organic mulches in the dry tropics of Australia" Abstract accepted for presentation to **XXVI International Horticultural Congress, Horticulture: Art and Science for Life**, Toronto, Canada, 11th-17th August, 2002

2. Poster session and International table "Sustainable Agriculture From around the World" at 7th annual Field Day **More Mouths, Less Land, Greater Expectations - A Balanced Approach!** Cedar Meadows Farm, Holtwood, PA 17532 USA 26th July, 2000.

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