Export cauliflower - Alternative planting configurations

Rachel Lancaster
Department of Agriculture & Food Western Australia

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Level 7
179 Elizabeth Street
Sydney NSW 2000
Telephone: (02) 8295 2300
Fax: (02) 8295 2399
E-Mail: horticulture@horticulture.com.au

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Alternative planting configurations for production of cauliflower and broccoli

Dr Kristen Stirling

Final Report for Project VG04008
(Project Completion Date: 25 January 2008)

Department of Agriculture and Food Western Australia

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Project leader
Ms Rachel Lancaster
Department of Agriculture and Food WA
PO Box 1231
BUNBURY WA 6231
Phone: 08 9780 6210
Fax: 08 9780 6136
Email: rlancaster@agric.wa.gov.au

Team members
Dr Kristen Stirling
Department of Agriculture and Food WA
PO Box 1231
BUNBURY WA 6231
Phone: 08 9780 6219
Fax: 08 9780 6136
Email: kstirling@agric.wa.gov.au

Mr Peter Gartrell
Department of Agriculture and Food WA
PO Box 1231
BUNBURY WA 6231
Phone: 08 9780 6178
Fax: 08 9780 6136
Email: pgartrell@agric.wa.gov.au

Mr David Tooke
Department of Agriculture and Food WA
PO Box 1231
BUNBURY WA 6231
Phone: 08 9780 0153
Fax: 08 9780 6136
Email: dtooke@agric.wa.gov.au

Mr Gavin D'adhemar
Department of Agriculture and Food WA
60 Abercrombie Road
MEDINA WA 6167
Phone: 08 9419 2908
Fax: 08 9419 2589
Email: gdadhemar@agric.wa.gov.au

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Purpose of the Report:
Project VG04008 investigated:

- Increasing planting density to improve yield and uniformity of maturation within cauliflower and broccoli crops;
- Alternative planting configurations as a method for increasing planting density and improving utilisation of land and machinery resources;
- Alternative methods of covering high density plantings of cauliflower;
- Economic evaluation of high density plantings and alternative row configurations and implications for farm profitability.

Date of Report: 25 January 2008

Contents

Media Summary

The best planting density and row configuration for production of vegetable brassica crops on loam and sandy soil types will depend largely on the curd/head specifications required by markets. This report provides detailed information on yield, size, weight and quality of cauliflower and broccoli grown at a range of planting densities and row configurations that can be used by producers to determine the most suitable arrangement for their current production system.

Results from this project indicate that planting density for both cauliflower and broccoli can be increased from that currently used in Western Australia to achieve higher yields of product suitable for both domestic and export markets. The best performing planting density for cauliflower grown on loam soil was 39,000 plants/ha arranged in a four row configuration which achieved an increased profit margin of $7,624/ha for product sold domestically. Broccoli can naturally be grown at much higher planting densities with crops cultivated in two, three and four row configurations from 39,000 plants/ha to 52,000 plants/ha providing the best results.

High density plantings were not as sustainable on sandy soils and although cauliflower planted at 39,000 plants/ha in a three row configuration produced the best yields and an increase in profit margin, the average weight of curds was reduced. Broccoli grown at 47,000 plants/ha in a two row configuration produced the best yields whilst maintaining an acceptable head size and weight on a sandy soil type. Plant density could be effectively increased by alteration of within row spacing in either a two, three or four row configuration allowing for more effective utilisation of available land and machinery resources.

Successfully increasing planting density to improve yield will require modification to current management programs. Nutrition and irrigation programs may need to be increased and crops will require consistent monitoring for potential pests and diseases. Investigation of alternative methods for covering of cauliflower crops indicated white shade cloth with a light transmission of 50% could be successfully used to prevent yellowing of curds and removed the need for crops to be manually covered.

Increasing planting density or altering row configurations did not significantly improve maturation uniformity of cauliflower and broccoli crops. However high density crops managed using techniques developed in project VG02051 for reducing the spread of harvest would facilitate the development of an intensively managed system which could be mechanically harvested. Mechanical harvesting will improve the competitiveness of the brassica industry by reducing labour costs and the need to source labour which is becoming increasingly difficult.

Technical Summary

Vegetable brassica producers are facing increasing costs of production necessitating greater efficiency in crop management. Increasing planting density is one method producers can use to more efficiently utilise available land, increase yield per hectare and the number of curds/heads within a crop which reach market specifications. Planting density can be increased by using row configurations and machinery commonly used for high density crops such as lettuce, which to be economically viable is planted in four rows per bed. Lettuce is an important rotational crop on sandy soil types and a greater return on capital invested in machinery could be achieved if several crops could be planted using the same machinery. Increasing planting density may also be a method for improving poor uniformity of crop maturity which currently results in extended harvest periods and high labour costs.

To determine how planting density and alternative row configurations affected the development of cauliflower and broccoli crops a series of field experiments were conducted. Experiments were conducted during all seasonal periods and on two soil types (loam and sandy soil type) as it was envisaged these two factors would have a significant effect on the development of crops at increased planting densities and alternative row configurations. The size, weight and quality of curds/heads grown at a range of planting densities and row configurations were recorded to determine yield, number of marketable heads per hectare and average weight and size. The number of harvests required to remove crops at each planting density and row configuration was also recorded to determine if crops grown at increased densities matured more uniformly. The management of crops grown in multiple row configurations at increased densities was also investigated.

The most suitable planting density and row configuration will be dependant on market specifications, soil type and management style. Cauliflower crops on a loam soil type could be successfully grown at 39,000 plants/ha in either a three or four row configuration whilst still maintaining curds at acceptable market specifications. On a sandy soil type, cauliflower crops were most suited to planting densities of 32,000 plants/ha to 39,000 plants/ha. Broccoli crops could be grown at much higher densities of 39,000 plants/ha to 52,000 plants/ha on loam soils with best results achieved at 47,000 plants/ha in a two row configuration on sandy soils. Similar yields were achieved by cauliflower and broccoli crops grown at the same planting density configured in either a two, three and four row configuration. These and other crops, such as lettuce, which is grown commercially in three and four row configurations could all be planted using a single machine. Increasing planting density or alteration of the row configuration did not improve the uniformity of crop maturation.

Management programs will need to be modified for crops grown at increased planting densities. In particular, the level of water and nutrients will need to be increased to ensure plant growth is not limited. Consistent monitoring for pest and disease pressure will be required as post-infection / infestation control may be difficult within high density crops. Covering of crops using shade cloth was investigated as an alternative to manual covering in high density crops. White shade cloth with a light transmission of 50% was shown to adequately prevent curd yellowing occurring and would reduce costs associated with labour required to cover curds by hand.

Introduction

In 2003/2004 the Australian export cauliflower industry was valued at $12.9 million with Western Australia providing 84% of exported product (ABS, 2007). Substantial competition, predominately by China, in traditional South East Asian markets has resulted in a fall in industry value to $1.5 million in 2006/2007 (ABS, 2007). Due to the significant decline in production of cauliflower for export markets, this project investigated alternative planting configurations for production of broccoli, which remains a substantial export vegetable crop in Australia, valued at $8.0 million in 2006/2007 (ABS, 2007). Domestic production of cauliflower and broccoli provides significant returns to the economy with total production of cauliflower and broccoli in 2004/2005 valued at $48.8 million and $73.5 million respectively (ABS, 2005).

The project investigated a range of planting configurations for cauliflower and broccoli which will assist in reducing the spread of harvest, achieve more curds/heads within export and domestic market specifications and increase the return on capital invested in planting machinery. Changes to planting configurations included increasing the number of rows per bed and adjusting the spacing between plants within a row to achieve an increase in planting density.

Cauliflower and broccoli producers commonly aim to maximise the number of curds/heads per crop which suit the specifications required by either domestic or export markets. Planting crops at different densities can be used to control the size of cauliflower curds and broccoli heads and contribute to uniform yield under defined growing conditions (Chung, 1985, Bracy *et al*., 1991, Jett *et al*., 1995). The minimum spacings to maintain market specifications for cauliflower and broccoli grown in multiple row configurations is currently unknown, despite being discussed among Western Australian vegetable brassica producers for several years.

Cauliflower crops are commonly grown commercially in a two row per bed configuration. Previous experimentation conducted in Western Australia has investigated increasing planting density by decreasing the within row spacing whilst maintaining a two row configuration. This research indicated yields could be increased whilst maintaining acceptable curd size and weight, however a limit on the number of plants per row is quickly reached before inter-plant competition starts to decrease yields. Increasing rectangularity of spacing (i.e. between-row spacing divided by within row spacing) decreases yields and crop uniformity, irrespective of genotype (Sutherland *et al*., 1989, Salter *et al*., 1984). That is, growing cauliflower crops closely spaced in wide-apart rows can be disadvantageous due to increased inter-plant competition. Increasing the rectangularity of spacing does provide some benefits such as wider spacing between the rows for easier cultivation and spraying, however growing plants on the square (decreased rectangularity) provides better light interception and allows plants to increase utilisation of resources such as growing area and soil nutrients. Square configurations and higher planting density can be achieved by increasing the number of rows per bed rather than decreasing within row spacing in a two row configuration (Sutherland *et al*., 1989).

Reduction of the labour component at harvest is of importance to the industry due to both the cost of labour and the increasing difficulties in accessing reliable, skilled labour. Improving the uniformity of crop maturation will reduce the number of harvests required to remove crops and decrease labour costs. Alteration of the row configuration and increasing planting density may improve uniformity of crop maturity with previous investigations reporting that closer spacing within row (decreasing rectangularity) resulted in more uniformly maturing crops of broccoli (Aldrich *et al.*, 1961) and cabbage (Miller *et al.*, 1969).

Previous experimental work has shown that cauliflower varieties can differ markedly in their response to changes in plant density (Salter and James, 1975). For this reason a number of different varieties were assessed at increased planting densities during this project. Salter and James (1975) found that at low planting densities varieties with large, broad leaves produced larger curds than that produced by smaller framed varieties however when plant density was increased the reverse occurred. While the larger framed variety was able to exploit the extra growing area and reach its yielding potential at lower planting density, the greater leafiness became a disadvantage at close spacing because of the greater competition pressure it exerted.

The main vegetable brassica production areas within Western Australia are located on either sandy or loam soil types. Lettuce is commonly used as a rotational crop with vegetable brassicas, particularly on sand plain soils. Vegetable brassica producers who grow on loam soils are diversifying their production base into other row crops such as lettuce. For economic viability, lettuce must be planted in either a three or four rows to a bed configuration, compared to the traditional two rows to a bed configuration for cauliflower. To improve the return on capital for lettuce planting machinery (approximately $15,000 per machine), the ability for producers to also use the machine for planting three and four rows of cauliflower and broccoli would be desirable. This would support the cauliflower industry by providing alternative rotational crops on loam soils, promoting diversification on farm and decreasing risks associated with limited cropping options.

Cauliflower and broccoli crops cultivated on sand or loam soils develop quite differently and require specific management techniques. Experiments were conducted on both soil types to ensure that alternative planting configurations are developed which are suitable for the majority of production areas. Environmental conditions such as temperature have a significant effect on how cauliflower and broccoli perform at increased planting densities and row configurations (Salter *et al.*, 1984). The various planting configurations were assessed in different seasonal conditions to monitor the impact of the environment on growth.

The aims of the project were:

- Determine alternative row configurations and planting densities for cauliflower and broccoli which produce the maximum number of heads/curds that meet market specifications
- Economic assessment of the impact of increasing planting density and the potential benefits for producers
- Demonstration of best row configurations and planting densities to cauliflower and broccoli producers

The implications for the vegetable brassica industry from this research is an increased potential for cost competitiveness due to an improvement in the effective utilisation of land and machinery resources; an increase in marketable yields and a reduction in labour costs (both actual on-ground costs and costs involved in sourcing adequate labour). The research can be used as a tool for growers to identify the best row configuration and planting density to achieve the maximum number of heads/curds within the crop which meet market specifications.

Materials and Methods

Loam soil site:

Field experiments were conducted at the Manjimup Horticultural Research Institute (south western region of Western Australia) from 2005 to 2007. The Institute is located on red earth soils which consist of a sandy loam surface changing gradually to a red clay subsoil. They are generally porous and well drained with ironstone gravel often present. These soils have a high water holding capacity but are highly weathered and usually deficient in phosphorus, nitrogen, zinc, molybdenum and occasionally copper. High levels of aluminium and iron oxides and a neutral to acid soil pH results in phosphorus being easily fixed in this soil (P.Tille, *pers comm*).

Soil Preparation: Soil was prepared by chisel ploughing and disc cultivation at least six weeks prior to transplanting so that previous plant residue was broken down. Trifluralin (herbicide) and chlorpyrifos (insecticide) were applied to the soil and incorporated two weeks prior to transplanting. At transplanting, a basal fertiliser was incorporated into a 20cm wide strip of soil surrounding the seedling. Fertiliser at the required rate was dropped in front of small rotary hoes and mixed through the soil to a depth of 10cm. A finger planter was used to transplant seedlings into two and three row configurations. A lettuce planting machine using cup-carousels was used to transplant seedlings into the four row configuration. Seedlings grown in two rows were planted in parallel while seedlings transplanted in three and four row configurations were off-set in each adjacent row so that a diamond pattern was created (Figure 1). All row configurations were tested on a raised bed, formed using a tractor with a wheel spacing of 1.7m. Seedlings were sourced from a commercial seedling nursery and transplanted at approximately six to eight weeks after seeding. Seedlings were irrigated immediately after transplanting and within 48 hours of transplanting, the herbicide metolachlor was applied.

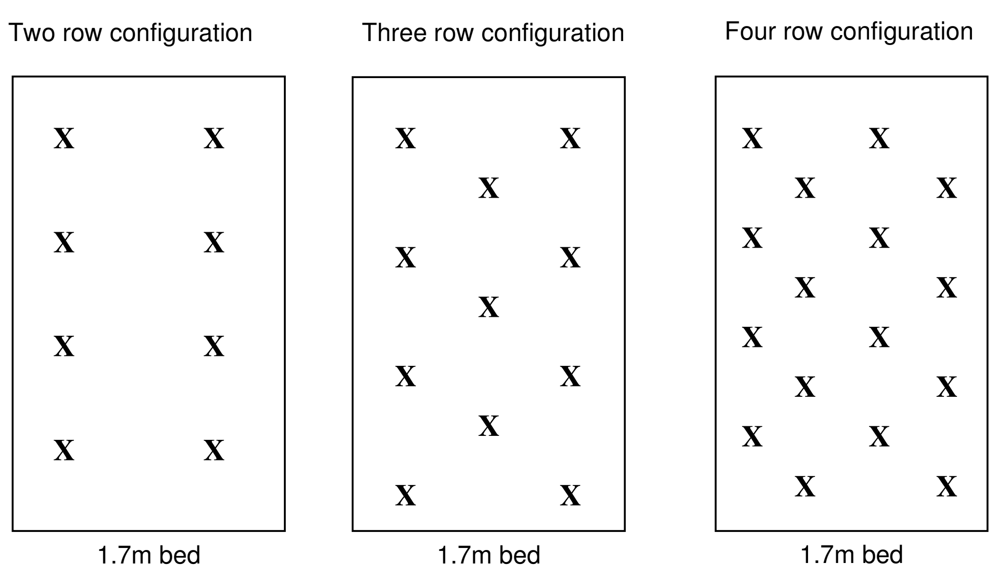


Figure 1: **Arrangement of seedlings planted in a two, three and four row per bed configuration.**

Figure 2: Experiment at loam soil site displaying two and four row configurations.

Fertiliser Program: Fertiliser was applied both at transplanting and post transplanting. To ensure the plants in the high density treatments were not nutritionally limited, the levels of N, P and K that each plant received were based on the number of plants within the highest density treatment. All treatments received 1600 kg/ha of Summit Spud® (6.9% N, 10.2% P, 10.2% K, 8.0% S, 0.15% Cu, 0.16% Zn, 0.9mg Mo, 0.15% Mn, 1.8% Ca) plus 1105 kg/ha of AllPhos® (20.5% P, 1.0% S, 15.0% Ca) at the time of planting. Nitrogen, boron, zinc and molybdenum were supplied to the plants as required throughout the growing season, using foliar application. All post transplant nitrogenous products were applied in a liquid form through a boom spray while under irrigation, to prevent fertiliser burn on the plants. The basic fertiliser program (Table 1) applied to all field experiments was adjusted slightly according to the growing season.

Table 1: Fertiliser program for field experiments conducted on a loam soil type

Time of Application	Product	Rate of Application (kg/ha)	Method of Application
At transplant	Summit Spud®	1600	Incorporated at planting
At transplant	AllPhos®	1105	Incorporated at planting
3 DAT	Potassium sulphate	100	Boom spray
3 DAT	Urea	50	Boom spray
11 DAT	Urea	75	Boom spray
13 DAT	Soluble boron	10	Boom spray
13 DAT	Sodium molybdate	1	Boom spray
13 DAT	Zinc sulphate	14	Boom spray
17 DAT	Calcium chelate	1	Boom spray
18 DAT	Urea	75	Boom spray
22 DAT	Soluble boron	10	Boom spray
22 DAT	Zinc sulphate	14	Boom spray
25 DAT	Urea	75	Boom spray
32 DAT	Urea	75	Boom spray
39 DAT	Urea	75	Boom spray
46 DAT	Potassium nitrate	100	Boom spray
52 DAT	Calcium nitrate	150	Boom spray
59 DAT	Calcium nitrate	100	Boom spray
69 DAT	Calcium nitrate	70	Boom spray (cauliflower only)
79 DAT	Calcium nitrate	50	Boom spray (cauliflower only)

DAT = Days After Transplanting
Boom spray = fertiliser applied in liquid form through boom spray, while irrigation was on.

Crop Management: Plants were watered according to 100% evaporation replacement of the previous day's epan. Tensiometers were placed within high density treatments to monitor the amount of available water. A monitoring program for insects and disease was conducted throughout the life of the crop and were controlled as required. Weeds were controlled prior to transplanting and post transplanting.

Sandy soil site:

Field experiments were conducted at the Medina Research Station (approximately 50km south of Perth, Western Australia) from 2005 to 2007. Medina Research Station is situated on Spearwood sands which are deep, siliceous, medium grained sands which are highly permeable. Despite having a low clay content, these sands are highly suited to irrigation with careful management. They generally have a neutral to slightly acid pH (P.Tille, *pers comm*).

Soil Preparation: Soil was irrigated prior to transplanting to encourage weed germination and glyphosate applied to control weeds as required. A rotary hoe was passed through the soil to incorporate previous crop material and metham sodium applied at 500 L/ha followed by a roller to seal the surface. The surface was irrigated for seven days and 10 to 14 days after application, a rotary hoe was again passed through the soil to release any latent fumigant. The base fertiliser was applied 2 to 3 days prior to transplanting and a rotary hoe used to incorporate fertiliser and form beds. A finger planter was used to transplant seedlings into two and three row configurations. A lettuce planting machine using cup-carousels was used to transplant seedlings into the four row configuration (Figure 3). Seedlings grown in two rows were planted in parallel while seedlings transplanted in three and four row configurations were off-set in each row so that a diamond pattern was created. All row configurations were tested on a raised bed formed using a tractor with a wheel spacing of 1.7m. Seedlings were sourced from a commercial seedling nursery and transplanted at approximately six to eight weeks after seeding. Once seedlings were transplanted, they were irrigated for approximately 40 minutes and the herbicide chlorthal-dimethyl was applied.

Figure 3: Finger planter (left) and carousel cup planter (right) used to arrange seedlings in two, three and four row per bed configurations.

Fertiliser Program: Fertiliser was applied both at transplanting and post transplanting. To ensure that plants in the high density treatments were not nutritionally limited, the levels of N, P and K that each plant received were based on the number of plants present in the highest density treatment. All treatments received 1600 kg/ha of Summit Spud® plus 550 kg/ha of AllPhos® which equated to approximately 274 kg/ha of phosphorus applied at the time of planting. Nitrogen was applied post transplant as potassium nitrate (13.4% N), Spurt (32% N) and calcium nitrate (15.5% N). Potassium and trace elements were also applied post-transplant and levels were increased to ensure that nutrition did not limit growth at the highest densities (Table 2). Slight adjustments to the basic fertiliser program applied to all field experiments were made according to the growing season.

Table 2: Post transplant fertiliser program for field experiments conducted on a sandy soil type.

Time of Application	Potassium nitrate (kg/ha)	SPURT® (kg/ha)	Calcium nitrate (kg/ha)	Magnesium sulphate (kg/ha)	Borax (kg/ha)	Sodium molybdate (kg/ha)
2 DAT	40					
4 DAT	35	35				
7 DAT	35	35				
10 DAT	40	40		7.5		0.5
14 DAT	40	40		7.5		0.5
17 DAT	47	58		7.5		
21 DAT	47	58		7.5		
24 DAT	50	70		7.5	7.5	
28 DAT	50	70		7.5	7.5	
31 DAT	55	70		7.5		
35 DAT	55	70		7.5		
38 DAT	55	75		7.5		
42 DAT	55	75		7.5		
45 DAT	60		100	7.5		
49 DAT	60		100	7.5		
52 DAT	60		70	7.5	5.5	
56 DAT	60		60	7.5	5.5	
59 DAT	60		60	7.5		
63 DAT	50		60	7.5		
66 DAT	40	15	50	7.5		
70 DAT	40	15	50	7.5		

DAT = Days After Transplanting

Crop Management: Plants were irrigated at 100% evaporation replacement for the first three days after transplanting. As crops developed they were irrigated according to 120% evaporation replacement. Tensiometers were placed within high density treatments to monitor the amount of available water. A monitoring program for insects and diseases was conducted throughout the life of the crop and infestations were controlled as required. Weeds were controlled prior to transplanting and post transplanting.

At both sites:

Vegetative Development: The fresh weight of the plant shoot (FWS) was measured at 6 weeks after transplanting (WAT). The FWS was obtained by removing the cauliflower and broccoli plants at ground level and weighing each plant individually. Six plants were sampled per plot.

At 6 WAT, two samples of the youngest fully mature leaf per plot were taken for nutrient analysis. The samples for all repetitions of each treatment were bulked together, providing a total of 6 samples per sampling time (one sample per treatment). Samples were dried and sent for analysis of total N, NO_3-N, NH_4-N, P and K.

Covering: Cauliflower curds were manually covered by bending the outer leaves surrounding the curd to form a protective barrier from the sun. This operation was conducted as required to prevent curd discolouration. Curds were covered whenever the curd was visible through the frame or if there was a risk that the curd may become visible before harvest.

Harvesting: All leaves were removed from around the cauliflower curd and broccoli head during the harvesting procedure so that an accurate estimation of yield could be made. Harvesting occurred every three to four days as required. Harvesting was delayed as long as possible, up to when curd/head quality would decrease if delayed longer. Broccoli was cut so the stem was about the same length as the diameter of the heads, giving an evenly proportioned head width and stem length.

Measurements: All harvested curds and heads were weighed so that an average curd/head weight in grams (g) and the total yield (tonnes) of curds/heads harvested per hectare could be calculated. The diameter of all heads/curds was measured using vernier callipers so that an average size of heads/curds for each planting configuration could be determined. Cauliflower and broccoli were graded to allow a comparison of their yield and quality to be made. Marketable yield of product suitable for export was measured in tonnes per hectare as product is sold by weight while yield of domestic standard product was recorded as the number of marketable curds/heads per hectare as product is sold in units. Quality specifications of export standard product are considerably more rigid than those expected of domestic market product.

Marketable yield of product was determined by the weight of the curd or head, a quality grade score and the density of the curd or head. Colour of the curd and head was also taken into account. An acceptable weight for cauliflower was a curd between 0.5 kg and 2 kg. The curd should be a round, domed shape and creamy white to white in colour. For cauliflower curds to be of export standard it must have a quality score of five or greater (with no visible defects or markings) and a density score of two or greater. A marketable cauliflower curd of domestic standards was considered acceptable with a quality score of four or more (with minor defects or markings) and a density score of two or greater.

An acceptable size for broccoli heads was between 5 cm and 20 cm in diameter or between 100 g and 800 g in weight. The head should be a green colour with no purple tinges. The quality score for export broccoli must be five or greater and density score two or greater. Domestic standard broccoli had a quality score of four or greater (with minor defects and markings) and a density score of two or greater.

The quality and density scores are not presented in the results as they are used only to separate poor quality curds or heads in the grading data sheets from those that are of a medium to high standard of quality.

The uniformity of curd weight within cauliflower crops was measured as the percentage of curds within the crop which weighed between 0.9 kg and 1.1 kg. Cauliflower curds weighing 1.0 kg had previously been identified as a desired weight for cauliflower sold on both domestic and export markets. For broccoli crops, the percentage of crop falling within three main weight categories was recorded (<300 g; 300 to 500 g; >500 g).

The uniformity of crop maturation was measured by the number of harvests required to completely remove the crop and the percentage of crop removed at each of those harvests. The percentage of crop within each planting density and row configuration which was rendered unmarketable due to two primary defects was recorded.

Statistical analysis: All experiments were arranged according to a randomised block design and data subjected to analysis of variance (ANOVA) using the Genstat 8 statistical package. Treatments were blocked across bays to account for changes in soil type and slope. Treatments were replicated five times in the majority of cauliflower experiments while replication of treatments within broccoli experiments ranged from two to five. The effect of row number (2 vs 3 vs 4) was assessed, with a P value less than 0.05 indicating a significant difference existed. The least significant difference (lsd) value indicated exactly which treatments were significantly different. The effect of increasing planting density within a row configuration was determined by linear and curvilinear response analysis to within-row spacing and a spacing contrast determined in experiments where only one variety was assessed and an lsd value determined where more than one variety was assessed. Where more than one variety was evaluated per seasonal period, the difference between varieties was statistically analysed and the interaction between variety, number of rows and within row spacing determined.

Treatment structure: Treatment structure was modified in response to the results from early experiments. All planting densities within cauliflower crops were compared against the industry standard of 29,000 plants/ha planted in a two row configuration. Initially a range of planting densities was tested from 29,000 plants/ha up to 59,000 plants/ha in a four row configuration. As the project progressed, planting densities above 39,000 plants/ha were identified as being too extreme and removed. Three row configurations were incorporated into the treatment structure so they could be compared against four row configurations and it was also determined that different varieties should be compared during each seasonal period. For each growing period one variety was selected for its known capacity to perform well during that season. The second variety chosen was new and it's capabilities less well known. Varieties for comparison were also selected for differences in plant frame size as this may have an affect on how the variety performs at increased planting densities. Initially, planting configurations were only investigated in cauliflower crops however during the second year of experimentation the effect of alternative planting configurations in broccoli crops was examined. A greater range of alternative planting configurations in broccoli was examined at the sandy soil site as there is a greater focus on broccoli production at this location.

The actual planting density (plants/ha) have been rounded up or down to the nearest 1000. The precise planting densities are displayed in Tables 20, 30, 40 and 46.

Loam soil - Cauliflower

Table 3: Treatment structure for field experiment 1.

Treatment	Planting Density (plants/ha)	Number of Rows	Between row spacing (cm)	Within row spacing (cm)
1	29,000	2	80	40
2	39,000	4	35	60
3	34,000	4	35	70
4	29,000	4	35	80

Table 4: Treatment structure for field experiment 2, 3 and 4.

Treatment	Planting density (plants/ha)	Number of rows	Between row spacing (cm)	Within row spacing (cm)
1	29,000	2	80	40
2	59,000	4	35	40
3	47,000	4	35	50
4	39,000	4	35	60
5	34,000	4	35	70
6	29,000	4	35	80

Table 5: Treatment structure for field experiment 5.

Treatment	Planting density (plants/ha)	Number of rows	Between row spacing (cm)	Within row spacing (cm)
1	29,000	2	80	40
2	47,000	4	35	50
3	39,000	4	35	60
4	29,000	4	35	80
5	50,000	3	45	35
6	39,000	3	45	45

Table 6: Treatment structure for field experiment 6, 7 and 8.

Treatment	Planting density (plants/ha)	Number of rows	Between row spacing (cm)	Within row spacing (cm)	Variety
1	29,000	2	80	40	Cultivar 1
2	29,000	2	80	40	Cultivar 2
3	39,000	3	45	45	Cultivar 1
4	39,000	3	45	45	Cultivar 2
5	39,000	4	35	60	Cultivar 1
6	39,000	4	35	60	Cultivar 2
7	29,000	4	35	80	Cultivar 1
8	29,000	4	35	80	Cultivar 2

Cultivar 1 = Monarch (experiment 6), Aviron (experiment 7) and Granite (experiment 8).
Cultivar 2 = Moby (experiment 6), Summer Love (experiment 7) and Starlight (experiment 8).

Loam soil - Broccoli

Table 7: Treatment structure for field experiment 1, 2 and 3 (year 2).

Treatment	Planting density (plants/ha)	Number of rows	Between row spacing (cm)	Within row spacing (cm)
1	59,000	4	35	40
2	47,000	4	35	50
3	59,000	3	45	30
4	44,000	3	45	40

Table 8: Treatment structure for field experiment 4 (year 2).

Treatment	Planting density (plants/ha)	Number of rows	Between row spacing (cm)	Within row spacing (cm)
1	39,000	2	80	30
2	44,000	3	45	40
3	51,000	2	80	23
4	52,000	4	35	45
5	59,000	3	45	30
6	69,000	4	35	34

Sandy soil type – Cauliflower

Table 9: Treatment structure for field experiment 1, 2 and 3.

Treatment	Planting density (plants/ha)	Number of rows	Between row spacing (cm)	Within row spacing (cm)
1	29,000	2	80	40
2	59,000	4	35	40
3	47,000	4	35	50
4	39,000	4	35	60
5	34,000	4	35	70
6	29,000	4	35	80

Table 10: Treatment structure for field experiment 4.

Treatment	Planting density (plants/ha)	Number of rows	Between row spacing (cm)	Within row spacing (cm)
1	29,000	2	80	40
2	50,000	3	45	35
3	39,000	3	45	45
4	32,000	3	45	55
5	47,000	4	35	50
6	39,000	4	35	60
7	34,000	4	35	70
8	29,000	4	35	80

Table 11: Treatment structure for field experiment 5 and 6.

Treatment	Planting density (plants/ha)	Number of rows	Between row spacing (cm)	Within row spacing (cm)	Variety
1	29,000	2	80	40	Cultivar 1
2	29,000	2	80	40	Cultivar 2
3	39,000	4	35	60	Cultivar 1
4	39,000	4	35	60	Cultivar 2
5	29,000	4	35	80	Cultivar 1
6	29,000	4	35	80	Cultivar 2
7	39,000	3	45	45	Cultivar 1
8	39,000	3	45	45	Cultivar 2

Cultivar 1 = Summer Love (experiment 5), Aviron (experiment 6).
Cultivar 2 = Fremont (experiment 5), Lisbon (experiment 6).

Table 12: Treatment structure for field experiment 7 and 8.

Treatment	Planting density (plants/ha)	Number of rows	Between row spacing (cm)	Within row spacing (cm)	Variety
1	29,000	2	80	40	Cultivar 1
2	29,000	2	80	40	Cultivar 2
3	39,000	2	80	30	Cultivar 1
4	39,000	2	80	30	Cultivar 2
5	29,000	4	35	60	Cultivar 1
6	29,000	4	35	60	Cultivar 2
7	29,000	3	45	60	Cultivar 1
8	29,000	3	45	60	Cultivar 2
9	39,000	3	45	45	Cultivar 1
10	39,000	3	45	45	Cultivar 2

Cultivar 1 = Amsterdam (experiment 7) and Aviron (experiment 8).
Cultivar 2 = Sirente (experiment 7) and Lisbon (experiment 8).

Sandy soil type - Broccoli

Table 13: Treatment structure for field experiment 1 (year 1).

Treatment	Planting density (plants/ha)	Number of rows	Between row spacing (cm)	Within row spacing (cm)
1	47,000	4	35	50
2	39,000	4	35	60
3	44,000	3	45	40
4	35,000	3	45	50

Table 14: Treatment structure for field experiment 2 (year 2).

Treatment	Planting density (plants/ha)	Number of rows	Between row spacing (cm)	Within row spacing (cm)	Variety
1	59,000	4	35	40	Ironman
2	59,000	4	35	40	Endurance
3	47,000	4	35	50	Ironman
4	47,000	4	35	50	Endurance
5	39,000	4	35	60	Ironman
6	39,000	4	35	60	Endurance
7	59,000	3	45	30	Ironman
8	59,000	3	45	30	Endurance
9	44,000	3	45	40	Ironman
10	44,000	3	45	40	Endurance
11	35,000	3	45	50	Ironman
12	35,000	3	45	50	Endurance
13	39,000	2	80	30	Ironman
14	39,000	2	80	30	Endurance
15	29,000	2	80	40	Ironman
16	29,000	2	80	40	Endurance

Table 15: Treatment structure for field experiment 3 (year 2).

Treatment	Planting density (plants/ha)	Number of rows	Between row spacing (cm)	Within row spacing (cm)	Variety
1	47,000	4	35	50	Ironman
2	47,000	4	35	50	Endurance
3	39,000	4	35	60	Ironman
4	39,000	4	35	60	Endurance
5	59,000	3	45	30	Ironman
6	59,000	3	45	30	Endurance
7	44,000	3	45	40	Ironman
8	44,000	3	45	40	Endurance
9	35,000	3	45	50	Ironman
10	35,000	3	45	50	Endurance
11	47,000	2	80	25	Ironman
12	47,000	2	80	25	Endurance
13	39,000	2	80	30	Ironman
14	39,000	2	80	30	Endurance
15	29,000	2	80	40	Ironman
16	29,000	2	80	40	Endurance

Table 16: Treatment structure for field experiment 4 (year 2).

Treatment	Planting density (plants/ha)	Number of rows	Between row spacing (cm)	Within row spacing (cm)	Variety
1	39,000	4	35	60	Ironman
2	39,000	4	35	60	Endurance
3	59,000	3	45	30	Ironman
4	59,000	3	45	30	Endurance
5	44,000	3	45	40	Ironman
6	44,000	3	45	40	Endurance
7	35,000	3	45	50	Ironman
8	35,000	3	45	50	Endurance
9	47,000	2	80	25	Ironman
10	47,000	2	80	25	Endurance
11	29,000	2	80	40	Ironman
12	29,000	2	80	40	Endurance

Table 17: Summary of field experimental program at loam and sandy soil site.

Crop	Soil type	Experiment	Time of year
Cauliflower	Loam	1	June – October 2004
		2	November 2004 - January 2005
		3	January - April 2005
		4	April - July 2005
		5	June - October 2005
		6	November 2005 - February 2006
		7	January - April 2006
		8	April – August 2006
	Sand	1	November 2004 – February 2005
		2	January - April 2005
		3	April - June 2005
		4	July - October 2005
		5	November 2005 - January 2006
		6	January - April 2006
		7	May - July 2006
		8	August - October 2006
Broccoli	Loam	1	November 2005 – February 2006
		2	January – April 2006
		3	April – August 2006
		4	December 2006 – February 2007
	Sand	1	January – April 2006
		2	May - July 2006
		3	August - November 2006
		4	March – May 2007

Results

Results are tabulated according to the main harvest characteristics assessed. Results are shown for each cauliflower and broccoli planting density and row configuration. The crops were cultivated over a two year period on both loam and sandy soil types.

Cauliflower – Loam Soil

Total Yield (tonnes per hectare)

- Increasing planting density significantly increased total yield during all field experiments except in experiment 4 (Table 18). Plants in this experiment were severely affected by an infection of Black Rot (*Xanthomonas campestris*) which reduced vegetative vigour and yield.
- No significant differences in total yield were observed between plants grown in either a 2 or 4 row configuration at a planting density of 29,000 plants/ha in field experiment 1, 2, 3, 4, 5, 6 (cv. Moby), 7 (cv. Aviron) and 8 (cv. Granite and cv. Starlight) (Table 18). In field experiment 6 (cv. Monarch) and 7 (cv. Summer Love), a significant increase in total yield was observed when plants were grown in 4 rows compared to 2 rows at 29,000 plants/ha. At 39,000 plants/ha, there was generally no significant difference in total yield between plants grown in either a 2, 3 or 4 row configuration. During field experiment 7, both 'Aviron' and 'Summer Love' produced significantly higher total yields when grown in a 4 row configuration compared to a 3 row configuration.
- During summer (experiment 6) and winter (experiment 8), a significant varietal effect on total yield was observed (Table 18). 'Monarch' consistently produced higher yields than 'Moby' at both 29,000 plants/ha and 39,000 plants/ha. 'Granite' consistently produced higher yields than 'Starlight' at both 29,000 plants/ha and 39,000 plants/ha. In autumn (experiment 7), no significant varietal effect on total yield was observed.

Table 18: Total yield (t/ha) of cauliflower grown at various planting densities and row configurations on a loam soil type.

Number of rows	Planting density (plants/ha)	Between row spacing x within row spacing (cm)	Experiment 1 Jun-Oct 04	Experiment 2 Nov 04-Jan 05	Experiment 3 Jan-Apr 05	Experiment 4 Apr-Jul 05	Experiment 5 Jun-Oct 05	Experiment 6 Nov 05-Feb 06		Experiment 7 Jan-Apr 06		Experiment 8 Apr-Aug 06	
			Virgin	Monarch	Summer Love	Brittany	Virgin	Monarch	Moby	Aviron	Summer Love	Granite	Starlight
2	29,000	80 x 40	27.59	32.73	28.62	19.17	31.18	31.48	27.95	32.95	29.59	24.88	19.61
4	29,000	35 x 80	25.61	34.32	30.42	19.63	30.08	33.97	28.77	33.05	32.19		
4	34,000	35 x 70	29.73	36.26	35.75	20.99							
2	39,000	80 x 30										26.95	24.89
3	39,000	45 x 45					33.14	37.58	33.95	36.73	35.77	25.42	22.81
4	39,000	35 x 60	31.06	40.41	39.73	23.05	34.44	38.89	32.13	39.64	38.81	26.85	22.78
4	47,000	35 x 50		40.67	42.49	23.86	36.41						
3	50,000	45 x 35					34.56						
4	59,000	35 x 40		43.87	45.53	21.74							
Number of rows effect: P value (lsd 5%)			ns	<0.001 (2.6)	<0.001 (2.5)	0.03 (2.4)	ns	<0.001 (2.4)		<0.001 (1.9)		ns	
Effect of planting density within each row configuration: P value (spacing contrast)			0.01 (-0.3)	<0.001 (-3.4)	<0.001 (-0.3)	ns	0.01 (-0.2)	ns		<0.001 (2.2)		<0.001 (1.9)	
Varietal effect: P value (lsd 5%)			ns	ns	ns	ns	ns	<0.001 (2.0)		ns		<0.001 (1.3)	
Interaction between variety, number of rows and spacing: P value (lsd 5%)			ns	ns	ns	ns	ns	0.005 (4.0)		ns		ns	

Marketable Yield (tonnes per hectare) – Export market specifications

- In experiment 1, 5, 6 (cv. Monarch) and 8, marketable yield did not increase significantly with increasing planting density (Table 19). In experiment 2, 3, 7 and 6 (cv. Moby) increasing planting density did significantly increase marketable yield. During experiment 4 marketable yield decreased significantly with increasing planting density which was attributed to Black Rot (*Xanthomonas campestris*) infection within the crop.
- Alteration of the row configuration at 29,000 plants/ha did not significantly affect the marketable yield produced during the majority of field experiments (Table 19). During experiments 2 and 6 (cv. Monarch), increasing the number of rows from 2 to 4 at 29,000 plants/ha resulted in a significant increase in marketable yield. However in experiment 6, the marketable yield produced by 'Moby'

plants decreased by 6.03 t/ha when the row number was increased from 2 to 4. At 39,000 plants/ha, there was generally no significant difference in the marketable yield produced by plants grown in either a 2, 3 or 4 row configuration. However marketable yield produced by ‘Moby’ decreased by 3.17 t/ha when the row number was increased from 3 to 4.

- There was a strong varietal effect observed within each season during experiment 6, 7 and 8 (Table 19). During summer ‘Monarch’ was a higher yielding variety than ‘Moby’ at both 29,000 plants/ha and 39,000 plants/ha. ‘Summer Love’ was a higher yielding variety than ‘Aviron’ at both 29,000 plants/ha and 39,000 plants/ha and ‘Granite’ was significantly higher yielding than ‘Starlight’ at both 29,000 plants/ha and 39,000 plants/ha.

Table 19: Marketable yield – export (t/ha) of cauliflower grown at various planting densities and row configurations on a loam soil type.

Number of rows	Planting density (plants/ha)	Between row spacing x within row spacing (cm)	Experiment 1 Jun-Oct 04	Experiment 2 Nov 04-Jan 05	Experiment 3 Jan-Apr 05	Experiment 4 Apr-Jul 05	Experiment 5 Jun-Oct 05	Experiment 6 Nov 05-Feb 06		Experiment 7 Jan-Apr 06		Experiment 8 Apr-Aug 06	
			Virgin	Monarch	Summer Love	Brittany	Virgin	Monarch	Moby	Aviron	Summer Love	Granite	Starlight
2	29,000	80 x 40	24.69	26.12	26.51	12.28	18.85	25.43	17.27	17.95	27.25	19.83	13.90
4	29,000	35 x 80	22.69	30.52	28.28	11.71	19.78	28.73	11.24	16.33	29.86		
4	34,000	35 x 70	25.85	31.93	32.65	12.41							
2	39,000	80 x 30										19.30	14.33
3	39,000	45 x 45					21.70	31.05	21.96	23.42	33.26	19.02	16.32
4	39,000	35 x 60	26.69	35.51	36.14	12.70	21.18	30.72	18.79	23.86	35.40	21.44	15.88
4	47,000	35 x 50		34.67	35.05	8.65	19.97						
3	50,000	45 x 35					17.40						
4	59,000	35 x 40		32.98	33.83	4.94							
Number of rows effect: P value (lsd 5%)			ns	0.01 (4.2)	<0.001 (2.7)	ns	ns	0.004 (2.7)		0.004 (2.9)		ns	
Effect of planting density within each row configuration: P value (spacing contrast)			ns	0.01 (-4.4)	0.004 (-0.1)	0.003 (0.2)	ns	ns		<0.001 (3.3)		ns	
Varietal effect: P value (lsd 5%)			ns	ns	ns	ns	ns	<0.001 (2.2)		<0.001 (2.3)		<0.001 (1.6)	
Interaction between variety and number of rows: P value (lsd 5%)			ns	ns	ns	ns	ns	0.03 (3.8)		ns		ns	
Interaction between variety, number of rows and spacing: P value (lsd 5%)			ns	ns	ns	ns	ns	0.004 (4.4)		ns		ns	

Number of marketable curds per hectare suitable for domestic market specifications

- Increasing planting density significantly increased the number of marketable curds harvested per hectare during all field experiments (Table 20).
- During experiments 1, 3, 4 and 5 there were no significant difference in the number of curds harvested between row configurations at both 29,000 plants/ha and 39,000 plants/ha (Table 20). During experiments 2, 8 and 7 (cv. Summer Love), increasing the number of rows per bed at a planting density of 29,000 plants/ha and 39,000 plants/ha significantly increased the number of curds harvested. Increasing the number of rows per bed to 4 at a planting density of 29,000 plants/ha and 39,000 plants/ha during experiment 6 (cv. Moby) significantly decreased the number of marketable curds harvested.
- There was a significant varietal effect within each season at both 29,000 plants/ha and 39,000 plants/ha during experiments 6, 7 and 8 (Table 20). 'Monarch' crops produced significantly more marketable curds per hectare than 'Moby' crops during experiment 6. Significantly more marketable curds per hectare were harvested from 'Summer Love' crops than 'Aviron' crops and 'Granite' crops produced significantly more marketable curds per hectare than 'Starlight' at 39,000 plants/ha.

Table 20: Number of marketable curds produced by cauliflower crops grown at various planting densities and row configurations on a loam soil type.

Number of rows	Planting density (plants/ha)	Between row spacing x within row spacing (cm)	Experiment 1 Jun-Oct 04	Experiment 2 Nov 04-Jan 05	Experiment 3 Jan-Apr 05	Experiment 4 Apr-Jul 05	Experiment 5 Jun-Oct 05	Experiment 6 Nov 05-Feb 06		Experiment 7 Jan-Apr 06		Experiment 8 Apr-Aug 06	
			Virgin	Monarch	Summer Love	Brittany	Virgin	Monarch	Moby	Aviron	Summer Love	Granite	Starlight
2	29,412	80 x 40	27417	24706	28529	26961	24314	28039	25980	21863	26275	23137	21176
4	29,412	35 x 80	28688	28529	27353	28118	26569	27157	22647	22353	28431		
4	33,613	35 x 70	32729	30882	33039	31667							
2	39,216	80 x 30										26667	24314
3	39,216	45 x 45					31471	35784	32255	29216	35033	29314	28725
4	39,216	35 x 60	38688	35686	38412	36275	30294	34804	30588	30294	37647	31373	26471
4	47,059	35 x 50		45098	44804	45294	36569						
3	50,420	45 x 35					32353						
4	58,824	35 x 40		54902	51569	47941							
Number of rows effect: P value (lsd 5%)			<0.001 (1828)	<0.001 (1522)	<0.001 (1995)	<0.001 (2716)	0.001 (3615)	<0.001 (1603)		<0.001 (1619)		<0.001 (2630)	
Effect of planting density within each row configuration: P value (spacing contrast)			<0.001 (-500)	<0.001 (-670)	<0.001 (-602)	<0.001 (-513)	<0.001 (-312)	<0.001 (1851)		<0.001 (1869)		0.03 (3037)	
Varietal effect: P value (lsd 5%)			ns	ns	ns	ns	ns	<0.001 (1309)		<0.001 (1322)		0.03 (2148)	
Interaction between variety, number of rows and spacing: P value (lsd 5%)			ns	ns	ns	ns	ns	ns		ns		ns	

Average curd weight (grams)

- Increasing planting density significantly decreased the average weight of curds during all field experiments except experiment 1 where curd weight was unaffected (Table 21).
- Alteration of the row configuration had no significant effect on the weight of curds produced during experiment 4, 6, 7 (cv. Summer Love) and 8 (cv. Starlight) at a planting density of both 29,000 plants/ha and 39,000 plants/ha (Table 21). At a planting density of 29,000 plants/ha curd weight decreased significantly when the number of rows was increased from 2 to 4 in experiment 1, 2, 5 and 7 (cv. Aviron). However curd weight increased by 121.22 grams when the row number was increased from 2 to 4 during

experiment 3. At a planting density of 39,000 plants/ha curd weight increased significantly when the number of rows was increased from 3 to 4 during experiment 5 and 7 (cv. Aviron). However in experiment 8, at a planting density of 39,000 plants/ha 'Granite' plants were 69.62 grams heavier when grown in a 2 row configuration rather than a 3 row configuration.

- At 29,000 plants/ha there was a significant varietal effect on the average curd weight in both a 2 and 4 row configuration (Table 21). At 39,000 plants/ha this effect was not significant for plants grown during experiment 7 however in experiment 6 and 8 significant differences were observed between varieties grown at 39,000 plants/ha in all row configurations.

Table 21: Average curd weight (g) of cauliflower grown at various planting densities and row configurations on a loam soil type.

Number of rows	Planting density (plants/ha)	Between row spacing x within row spacing (cm)	Experiment 1 Jun-Oct 04	Experiment 2 Nov 04-Jan 05	Experiment 3 Jan-Apr 05	Experiment 4 Apr-Jul 05	Experiment 5 Jun-Oct 05	Experiment 6 Nov 05-Feb 06		Experiment 7 Jan-Apr 06		Experiment 8 Apr-Aug 06	
			Virgin	Monarch	Summer Love	Brittany	Virgin	Monarch	Moby	Aviron	Summer Love	Granite	Starlight
2	29,000	80 x 40	1004.03	1257.53	970.57	678.76	1101.40	1062.84	937.52	1213.61	1086.64	845.07	697.22
4	29,000	35 x 80	920.14	1177.84	1091.79	650.80	975.60	1181.74	978.30	1133.65	1078.20		
4	34,000	35 x 70	861.09	1120.13	1054.41	617.74							
2	39,000	80 x 30										734.55	613.10
3	39,000	45 x 45					814.65	985.15	928.37	978.04	960.46	664.93	602.81
4	39,000	35 x 60	819.03	1087.47	964.59	578.47	1062.89	1041.81	870.65	1036.61	1001.41	690.85	640.89
4	47,000	35 x 50		871.26	901.69	461.76	854.02						
3	50,000	45 x 35					769.43						
4	59,000	35 x 40		748.51	772.14	371.99							
Number of rows effect: P value (lsd 5%)			0.01 (15.0)	<0.001 (57.5)	<0.001 (67.9)	0.001 (57.5)	<0.001 (100.0)	ns		<0.001 (57.0)		<0.001 (45.0)	
Effect of planting density within each row configuration: P value (spacing contrast)			ns	<0.001 (11.1)	<0.001 (7.9)	0.001 (7.4)	<0.001 (10.8)	0.001 (7.0)		0.01 (6.6)		<0.001 (5.2)	
Varietal effect: P value (lsd 5%)			ns	ns	ns	ns	ns	<0.001 (49.2)		0.02 (46.5)		<0.001 (36.8)	
Interaction between variety, number of rows and spacing: P value (lsd 5%)			ns	ns	ns	ns	ns	ns		ns		ns	

Average curd size (curd diameter (cm))

- Increasing planting density did not significantly affect the average size of curds in experiment 1, 6, 7 and 8 (Table 22). In experiment 2, 3 and 4 increasing planting density within a 4 row configuration significantly decreased curd size. In experiment 5 curd size was observed to increase by 0.75 cm when planting density was increased from 29,000 plants/ha to 39,000 p/ha in a four row configuration.
- Alteration of the row configuration at 29,000 plants/ha did not significantly affect average curd size in experiment 1, 2, 3, 4, 6 and 8 (Table 22). During experiment 5 and 7 increasing the number of rows from 2 to 4 at a planting density of 29,000 plants/ha significantly decreased the average curd size. At a planting density of 39,000 plants/ha increasing the number of rows from 3 to 4 significantly increased the average size of curds in experiment 5 and 7.
- ‘Monarch’ and ‘Moby’ produced the same sized curds during experiment 6 (Table 22). ‘Aviron’ produced significantly larger curds than ‘Summer Love’ plants at all planting densities and row configurations in experiment 7. ‘Granite’ produced larger curds than ‘Starlight’ when grown in a 2 row configuration at 39,000 plants/ha however in a 3 and 4 row configuration there was no significant difference in the average size of curds.

Table 22: Average curd size (diameter (cm)) of cauliflower grown at various planting densities and row configurations on a loam soil type.

Number of rows	Planting density (plants/ha)	Between row spacing x within row spacing (cm)	Experiment 1 Jun-Oct 04	Experiment 2 Nov 04-Jan 05	Experiment 3 Jan-Apr 05	Experiment 4 Apr-Jul 05	Experiment 5 Jun-Oct 05	Experiment 6 Nov 05-Feb 06		Experiment 7 Jan-Apr 06		Experiment 8 Apr-Aug 06	
			Virgin	Monarch	Summer Love	Brittany	Virgin	Monarch	Moby	Aviron	Summer Love	Granite	Starlight
2	29,000	80 x 40	15.12	15.40	15.28	13.88	16.97	15.46	15.82	16.66	15.64	15.55	15.04
4	29,000	35 x 80	14.53	14.95	15.93	13.71	15.69	15.93	16.15	16.05	15.32		
4	34,000	35 x 70	14.43	14.75	15.69	13.44							
2	39,000	80 x 30										15.53	14.26
3	39,000	45 x 45					15.25	15.16	15.88	15.48	14.74	14.77	14.29
4	39,000	35 x 60	14.40	14.64	15.17	13.25	16.44	15.54	15.57	15.95	15.25	14.72	14.30
4	47,000	35 x 50		13.79	14.96	12.55	15.40						
3	50,000	45 x 35					15.47						
4	59,000	35 x 40		12.70	14.27	11.83							
Number of rows effect: P value (lsd 5%)			0.01 (0.65)	<0.001 (0.58)	ns	0.004 (0.6)	<0.001 (0.8)	ns		<0.001 (0.3)		ns	
Effect of planting density within each row configuration: P value (spacing contrast)			ns	<0.001 (0.75)	<0.001 (0.04)	<0.001 (0.05)	0.007 (0.4)	ns		ns		ns	
Varietal effect: P value (lsd 5%)			ns	ns	ns	ns	ns	ns		<0.001 (0.27)		0.04 (0.62)	
Interaction between variety, number of rows and spacing: P value (lsd 5%)			ns	ns	ns	ns	ns	ns		ns		ns	

Uniformity of curd weight (percentage of curds within crop that weigh between 0.9 kg and 1.1 kg)

- The percentage of curds which weighed approximately 1.0 kg was not significantly affected by increasing planting density (Table 23). Exceptions to this occurred during experiment 3 and 4 where the uniformity of curd weight significantly decreased as planting density increased from 34,000 plants/ha to 59,000 plants/ha.
- At 29,000 plants/ha the percentage of curds weighing between 0.9 kg and 1.1 kg was not significantly affected by an increase in row number from 2 to 4 (Table 23). Exceptions to this occurred during experiment 4, 6 (cv. Monarch) and 8 (cv. Granite) where the number of curds weighing approximately 1.0 kg decreased significantly when the number of rows per bed was increased to 4 at

both 29,000 plants/ha and 39,000 plants/ha. During experiment 7 (cv. Aviron) at 29,000 plants/ha, the percentage of curds weighing approximately 1.0 kg increased by 5.9% when the number of rows was increased from 2 to 4.

- There was a significant varietal effect observed during experiment 7 and 8 (Table 23). During experiment 7 ‘Summer Love’ produced more curds weighing approximately 1.0 kg than ‘Aviron’ at both 29,000 plants/ha and 39,000 plants/ha. During experiment 8, ‘Granite’ produced significantly more curds weighing approximately 1.0 kg than ‘Starlight’ at both planting densities.

Table 23: Uniformity of curd weight (percentage of curds which weigh between 0.9 kg and 1.1 kg) within cauliflower crops grown at various planting densities and row configurations on a loam soil type.

Number of rows	Planting density (plants/ha)	Between row spacing x within row spacing (cm)	Experiment 1 Jun-Oct 04	Experiment 2 Nov 04-Jan 05	Experiment 3 Jan-Apr 05	Experiment 4 Apr-Jul 05	Experiment 5 Jun-Oct 05	Experiment 6 Nov 05-Feb 06		Experiment 7 Jan-Apr 06		Experiment 8 Apr-Aug 06	
			Virgin	Monarch	Summer Love	Brittany	Virgin	Monarch	Moby	Aviron	Summer Love	Granite	Starlight
2	29,000	80 x 40	21.67	16.33	35.00	15.33	23.00	28.00	24.33	16.50	26.00	19.34	12.22
4	29,000	35 x 80	24.00	21.33	29.33	9.67	20.00	17.00	23.00	22.40	27.40		
4	34,000	35 x 70	20.00	22.03	37.39	10.14							
2	39,000	80 x 30										18.59	9.80
3	39,000	45 x 45					25.75	38.50	25.75	24.60	31.00	10.86	9.34
4	39,000	35 x 60	23.94	25.00	36.50	7.25	24.50	25.75	21.75	25.00	30.00	14.83	9.79
4	47,000	35 x 50		25.83	31.88	5.00	25.00						
3	50,000	45 x 35					17.09						
4	59,000	35 x 40		15.83	18.50	1.17							
Number of rows effect: P value (lsd 5%)			ns	ns	ns	<0.001 (4.4)	ns	0.005 (5.9)		0.045 (4.7)		0.001 (2.4)	
Effect of planting density within each row configuration: P value (spacing contrast)			ns	ns	0.01 (0.3)	0.003 (0.2)	ns	ns		ns		ns	
Varietal effect: P value (lsd 5%)			ns	ns	ns	ns	ns	ns		0.002 (3.8)		<0.001 (2.0)	
Interaction between variety and number of rows: P value (lsd 5%)			ns	ns	ns	ns	ns	ns		ns		ns	

Uniformity of curd maturation: Number of harvests

- In general increasing planting density did not significantly affect the number of harvests required to remove the crop (Table 24). Exceptions to this occurred in experiment 4 and 6 (cv. Moby) where increasing planting density did significantly increase the number of harvests required.
- Alteration of row configuration at 29,000 plants/ha and 39,000 plants/ha generally did not significantly affect the number of harvests required (Table 24). Exceptions to this occurred in experiment 2 and 6 (cv. Moby) where increasing the number of rows per bed to 4 did significantly increase the number of harvests required.
- No significant varietal effect was observed during experiment 6 (Table 24). During experiment 7 and 8, there was a significant varietal affect where ‘Summer Love’ plants required more harvests than ‘Aviron’ and ‘Starlight’ plants required more harvests than ‘Granite’ plants.

Table 24: Uniformity of curd maturation (number of harvests) within cauliflower crops grown at various planting densities and row configurations on a loam soil type.

Number of rows	Planting density (plants/ha)	Between row spacing x within row spacing (cm)	Experiment 1 Jun-Oct 04	Experiment 2 Nov 04-Jan 05	Experiment 3 Jan-Apr 05	Experiment 4 Apr-Jul 05	Experiment 5 Jun-Oct 05	Experiment 6 Nov 05-Feb 06		Experiment 7 Jan-Apr 06		Experiment 8 Apr-Aug 06	
			Virgin	Monarch	Summer Love	Brittany	Virgin	Monarch	Moby	Aviron	Summer Love	Granite	Starlight
2	29,000	80 x 40	2.83	2.20	3.00	3.00	1.60	3.00	3.00	2.20	3.00	1.60	2.00
4	29,000	35 x 80	2.83	3.00	3.00	2.60	2.00	3.00	3.00	2.60	3.00	1.40	2.00
4	34,000	35 x 70	3.00	3.20	3.00	2.80							
2	39,000	80 x 30										1.40	2.00
3	39,000	45 x 45					2.00	3.00	2.00	3.00	3.00	1.40	2.00
4	39,000	35 x 60	3.00	3.40	3.00	3.00	2.00	3.00	4.00	2.60	3.60	1.40	2.00
4	47,000	35 x 50		3.20	3.00	3.00	2.00						
3	50,000	45 x 35					2.00						
4	59,000	35 x 40		3.40	3.00	3.00							
Number of rows effect: P value (lsd 5%)			ns	<0.001 (0.5)	ns	ns	ns	<0.001 (0.3)		ns		ns	
Effect of planting density within each row configuration: P value (spacing contrast)			ns	ns	ns	0.027 (-0.01)	ns	ns		ns		ns	
Varietal effect: P value (lsd 5%)			ns	ns	ns	ns	ns	ns		0.009 (0.4)		<0.001 (0.2)	
Interaction between variety and number of rows: P value (lsd 5%)			ns	ns	ns	ns	ns	0.033 (0.4)		ns		ns	
Interaction between variety, number of rows and spacing: P value (lsd 5%)			ns	ns	ns	ns	ns	0.05 (0.3)		ns		ns	

Uniformity of curd maturation: Percentage of total yield removed at each harvest

Experiment 1: Increasing planting density appeared to have little effect on the percentage of total yield removed at each harvest (Figure 4). At the third harvest significantly less of the total yield was picked for plants grown at 29,000 plants/ha in a 2 row configuration. This indicates these plants matured earlier than those in the 4 row configurations.

Experiment 2: Plants grown at 29,000 plants/ha required only 3 harvests compared to plants grown at higher planting densities which required 4 harvests (Figure 4). This indicates that plants at the lower density matured more uniformly than those at higher planting densities. Plants grown at 29,000 plants/ha in a 2 row configuration matured earlier than those in the 4 row configurations with significantly more of the total yield harvested during the first pick.

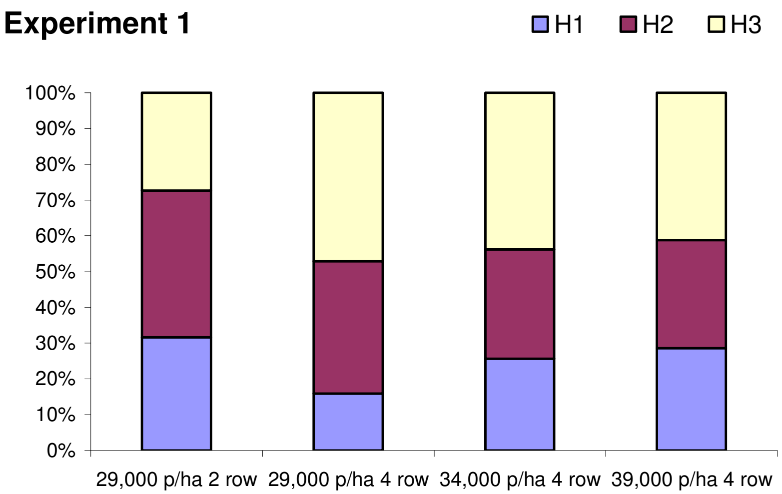
Experiment 3 and 4: There were no obvious differences between crops grown at the various planting densities and row configurations (Figure 4). All crops appeared to mature reasonably evenly with similar percentages of total yield removed at each harvest.

Experiment 5: Plants grown at 29,000 plants/ha matured earlier than those at higher planting densities particularly when cultivated in a 2 row configuration (Figure 4). Plants at 29,000 plants/ha also matured more uniformly with a higher percentage of the crop mature at the one time (H1).

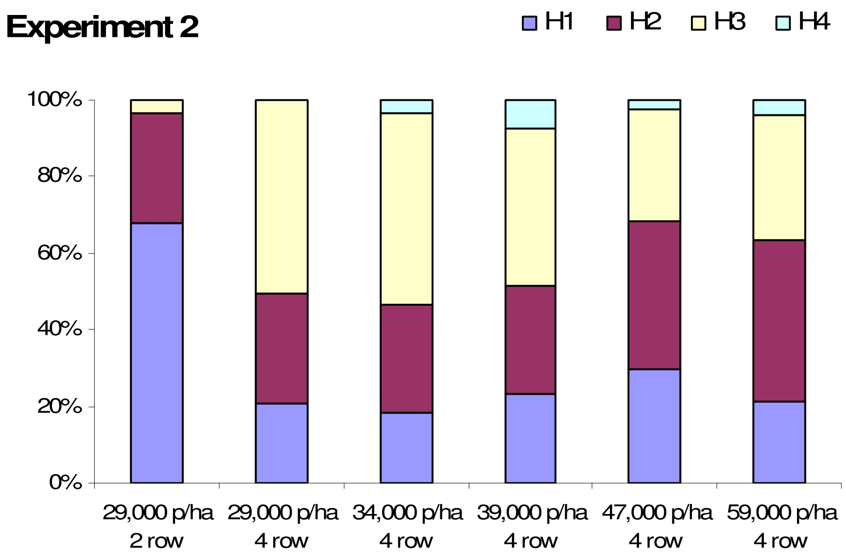
Experiment 6 – 'Monarch': Plants grown at 39,000 plants/ha in a 3 row configuration appeared to be the most uniform with the majority of the crop removed during the first 2 harvests (Figure 4). Plants grown at 39,000 plants/ha in a 4 row configuration matured slightly later than the rest of the treatments with a greater percentage of the crop picked at the third harvest. Plants grown at 29,000 plants/ha matured evenly with 3 picks required for those configured in both 2 and 4 rows.

Experiment 6 – 'Moby': Plants grown in a 3 row configuration at 39,000 plants/ha matured the most uniformly with approximately 50% of the crop ready at each of the first two harvests (Figure 4). Plants in a 4 row configuration at 39,000 plants/ha matured the least uniformly and required 4 harvests to completely remove the crop. Plants grown at 29,000 plants/ha required 3 harvests with the majority of the crop picked during the second harvest. No major differences were observed between row configurations when plants were grown at 29,000 plants/ha.

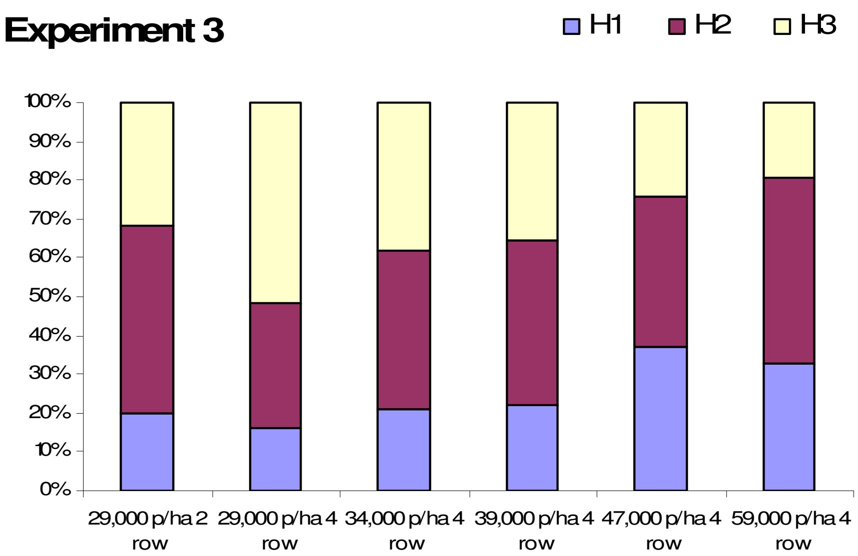
Experiment 7 – ‘Summer Love’:	Increasing planting density resulted in plants maturing later (Figure 4). The earliest maturing plants were those grown at 29,000 plants/ha in a 2 row configuration. Plants grown at 39,000 plants/ha in a 3 row configuration matured the most uniformly with the majority of the crop removed in 3 harvests while plants grown in other configurations were removed in 4 harvests.
Experiment 7 – ‘Aviron’:	Plants grown at 29,000 plants/ha matured earlier than plants grown at 39,000 plants/ha with a greater percentage of the crop removed at the first harvest (Figure 4). Plants grown at 29,000 plants/ha in a 2 row configuration matured the most uniformly with the majority of the crop picked over two harvests, while plants in other configurations were removed over 3 and 4 harvests. ‘Aviron’ generally matured earlier than ‘Summer Love’ at all planting densities and row configurations.
Experiment 8 – ‘Starlight’:	Plants grown at all planting densities and row configurations matured together with approximately 40% of the crop removed during the first harvest (Figure 4).
Experiment 8 – ‘Granite’:	Plants grown at all planting densities and row configuration matured reasonably evenly with similar percentages of total yield removed at each harvest (Figure 4). ‘Granite’ matured earlier than ‘Starlight’.



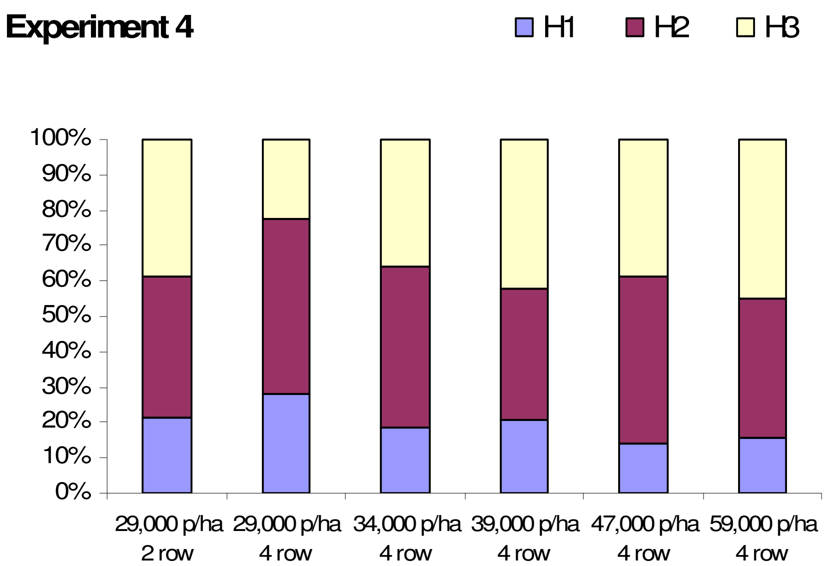
Experiment 1
H1
H2
H3
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
29,000 p/ha 2 row
29,000 p/ha 4 row
34,000 p/ha 4 row
39,000 p/ha 4 row

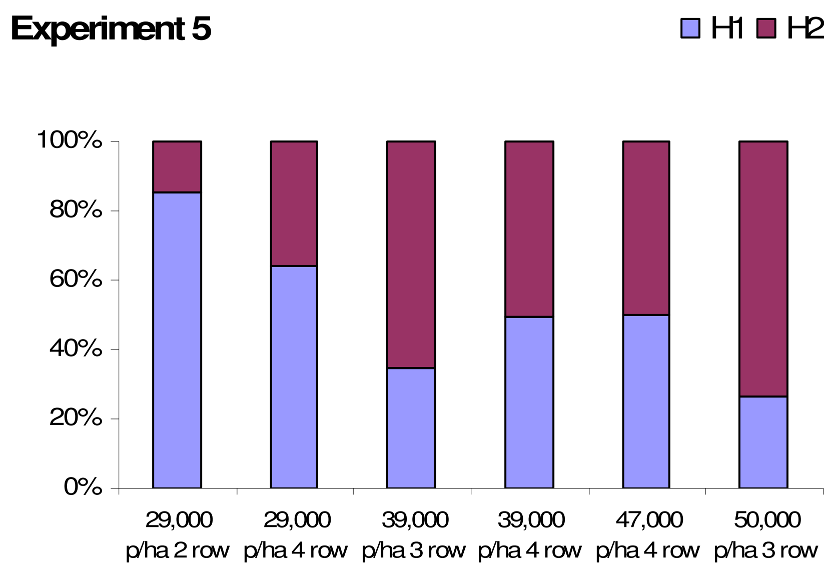


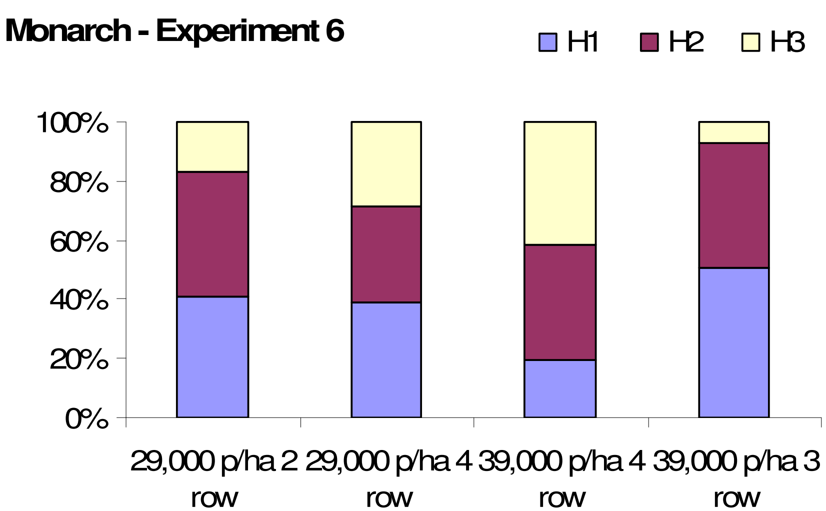
Experiment 2
H1
H2
H3
H4
100%
80%
60%
40%
20%
0%
29,000 p/ha 2 row
29,000 p/ha 4 row
34,000 p/ha 4 row
39,000 p/ha 4 row
47,000 p/ha 4 row
59,000 p/ha 4 row

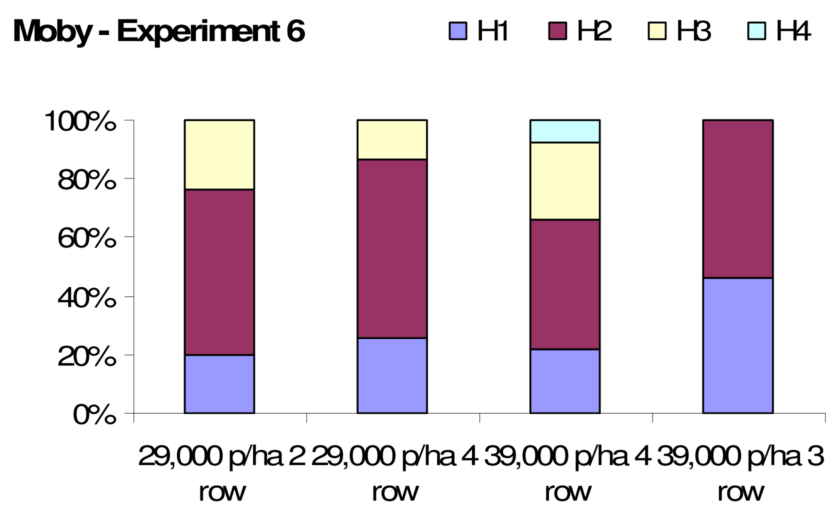


Experiment 3
H1
H2
H3
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
29,000 p/ha 2 row
29,000 p/ha 4 row
34,000 p/ha 4 row
39,000 p/ha 4 row
47,000 p/ha 4 row
59,000 p/ha 4 row


Experiment 4
H1
H2
H3
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
29,000 p/ha 2 row
29,000 p/ha 4 row
34,000 p/ha 4 row
39,000 p/ha 4 row
47,000 p/ha 4 row
59,000 p/ha 4 row


Experiment 5
H1
H2
100%
80%
60%
40%
20%
0%
29,000 p/ha 2 row
29,000 p/ha 4 row
39,000 p/ha 3 row
39,000 p/ha 4 row
47,000 p/ha 4 row
50,000 p/ha 3 row


Monarch - Experiment 6
H1
H2
H3
100%
80%
60%
40%
20%
0%
29,000 p/ha 2 row
29,000 p/ha 4 row
39,000 p/ha 4 row
39,000 p/ha 3 row


Moby - Experiment 6
H1
H2
H3
H4
100%
80%
60%
40%
20%
0%
29,000 p/ha 2 row
29,000 p/ha 4 row
39,000 p/ha 4 row
39,000 p/ha 3 row

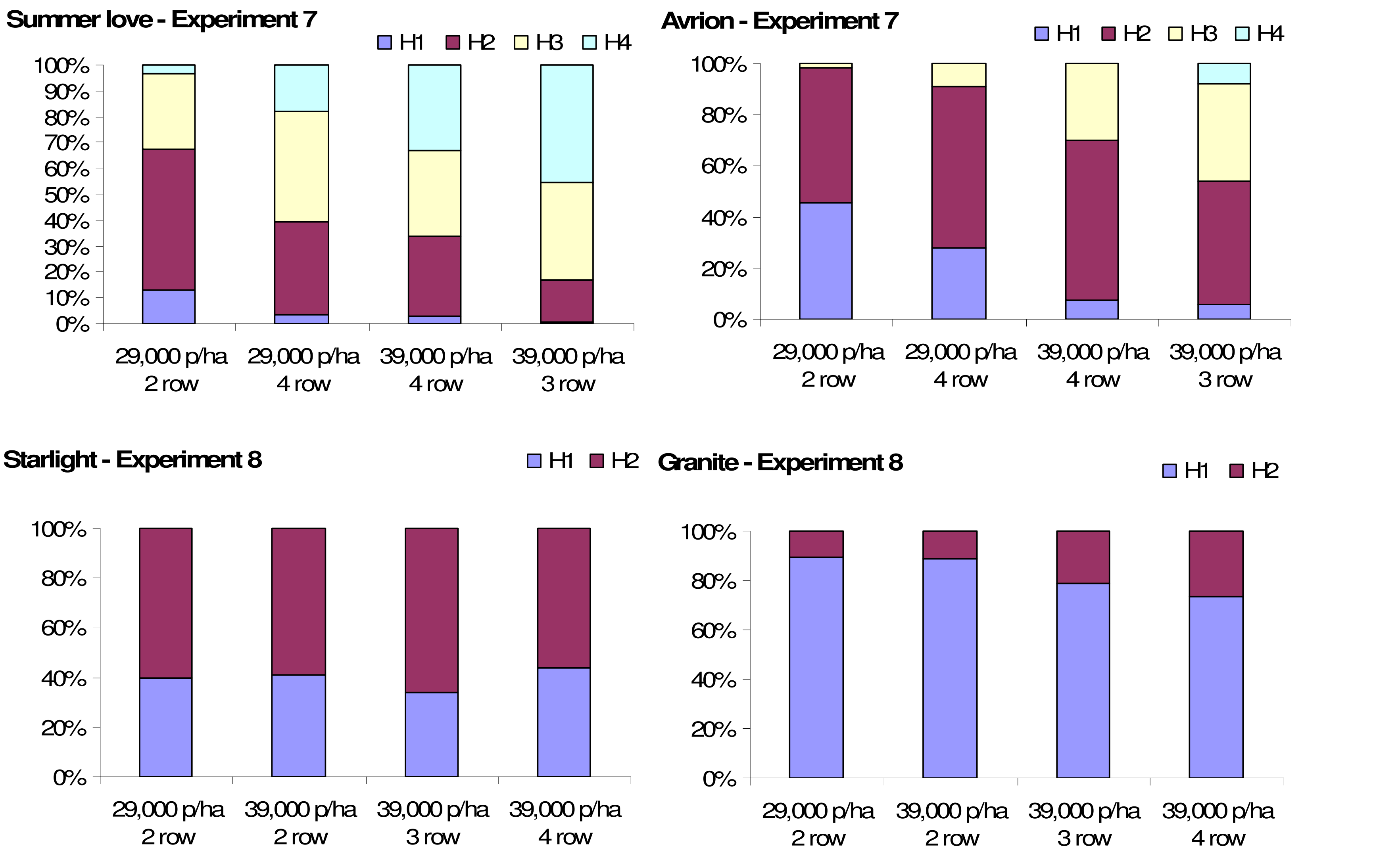


Figure 4: Percentage of total yield (t/ha) removed at each harvest during eight field experiments conducted at the loam soil site.

Rejection reasons
The two primary reasons why cauliflower curds were not considered acceptable for market specifications were yellowing (discolouration of curds due to sun exposure) and reduced curd weight (less than 500g).

'Yellowing' (percentage of curds within crop which display yellow discolouration)

- Increasing planting density did not significantly affect the percentage of yellow curds within the crop in experiment 1, 3, 4, 6 and 8 (Table 25). In experiment 2 (summer), 5 (winter) and 7 (autumn) the percentage of yellow curds within the crop increased significantly with increasing planting density.
- Alteration of row configuration did not significantly affect the percentage of yellow curds (Table 25). An exception to this was in experiment 8 where 'Granite' crops grown in a 2 row configuration at a planting density of 39,000 plants/ha contained significantly more yellow curds than crops grown in a 3 or 4 row configuration.
- There was a significant varietal effect on the percentage of yellow curds within crops (Table 25). 'Monarch' crops had significantly more yellow curds than crops of 'Moby'. Crops of 'Aviron' contained significantly more yellow curds than crops of 'Summer Love' except when grown at 39,000 plants/ha in a 4 row configuration where no significant difference occurred. Crops of 'Granite' contained more yellow curds than crops of 'Starlight' although this effect was less noticeable when plants were grown at 39,000 plants/ha in a 3 and 4 row configuration.

Table 25: Percentage of yellow curds within cauliflower crops grown at various planting densities and row configurations on a loam soil type.

Number of rows	Planting density (plants/ha)	Between row spacing x within row spacing (cm)	Experiment 1 Jun-Oct 04	Experiment 2 Nov 04-Jan 05	Experiment 3 Jan-Apr 05	Experiment 4 Apr-Jul 05	Experiment 5 Jun-Oct 05	Experiment 6 Nov 05-Feb 06		Experiment 7 Jan-Apr 06		Experiment 8 Apr-Aug 06	
			Virgin	Monarch	Summer Love	Brittany	Virgin	Monarch	Moby	Aviron	Summer Love	Granite	Starlight
2	29,000	80 x 40	19.32	20.00	4.33	22.33	23.33	25.00	7.00	15.00	10.92	9.41	1.42
4	29,000	35 x 80	8.47	17.67	7.67	21.33	21.67	24.00	6.00	12.11	5.28		
4	34,000	35 x 70	17.13	17.97	6.67	22.32							
2	39,000	80 x 30										7.55	1.88
3	39,000	45 x 45					29.00	27.75	11.25	19.08	11.74	2.60	1.57
4	39,000	35 x 60	16.13	20.75	5.25	23.50	25.67	26.25	6.25	16.06	14.22	2.30	1.05
4	47,000	35 x 50		24.79	4.79	22.71	44.00						
3	50,000	45 x 35					37.00						
4	59,000	35 x 40		36.17	5.67	12.33							
Number of rows effect: P value (lsd 5%)			ns	ns	ns	ns	ns	ns		ns		0.02 (2.7)	
Effect of planting density within each row configuration: P value (spacing contrast)			ns	0.002 (-0.4)	ns	ns	0.008 (-0.7)	ns		0.002 (3.8)		ns	
Varietal effect: P value (lsd 5%)			ns	ns	ns	ns	ns	<0.001 (3.9)		<0.001 (2.7)		<0.001 (2.2)	
Interaction between variety and number of rows: P value (lsd 5%)			ns	ns	ns	ns	ns	ns		ns		ns	

Rejection reasons

'Too small' (Percentage of curds within crop which weigh below 500g)

- Increasing planting density significantly increased the number of curds which weighed below 500g in experiment 2, 4, 5 and 6 (cv. Moby). In all other experiments increasing planting density did not significantly affect the percentage of 'too small' curds (Table 26).
- At 29,000 plants/ha alteration of the row configuration did not significantly affect the percentage of curds within the crop which weighed below 500g except during experiment 1 where the percentage of low weight curds increased by 9.13% when the number

of rows was increased from 2 to 4 (Table 26). In experiment 8 the row configuration used at a planting density of 39,000 plants/ha had a significant effect on the percentage of small curds within the crop. Crops grown in a 3 row configuration contained significantly more curds below 500g than those in a 2 or 4 row configuration and crops grown in a 4 row configuration contained significantly more small curds than crops grown in a 2 row configuration.

- A strong varietal difference was observed in experiment 6 and 8 (Table 26). ‘Moby’ had a higher percentage of ‘too small’ curds than ‘Monarch’ at all planting densities and row configurations. Within a 2 row configuration ‘Starlight’ had a higher percentage of ‘too small’ curds than ‘Granite’ however in a 3 and 4 row configuration ‘Starlight’ had slightly less curds weighing below 500g than ‘Granite’. In experiment 7 ‘Aviron’ and ‘Summer Love’ had the same percentage of small curds within the crop.

Table 26: Percentage of curds which weigh below 500g within crops grown at various planting densities and row configurations on a loam soil type.

Number of rows	Planting density (plants/ha)	Between row spacing x within row spacing (cm)	Experiment 1 Jun-Oct 04	Experiment 2 Nov 04-Jan 05	Experiment 3 Jan-Apr 05	Experiment 4 Apr-Jul 05	Experiment 5 Jun-Oct 05	Experiment 6 Nov 05-Feb 06		Experiment 7 Jan-Apr 06		Experiment 8 Apr-Aug 06	
			Virgin	Monarch	Summer Love	Brittany	Virgin	Monarch	Moby	Aviron	Summer Love	Granite	Starlight
2	29,000	80 x 40	3.41	2.00	2.33	17.67	1.00	2.67	6.33	3.99	3.07	7.11	11.82
4	29,000	35 x 80	12.54	2.67	1.00	23.33	5.00	1.33	3.67	2.29	3.90		
4	34,000	35 x 70	11.52	2.32	0.58	23.77							
2	39,000	80 x 30										9.03	11.64
3	39,000	45 x 45					13.67	2.00	4.50	4.74	3.95	16.66	16.10
4	39,000	35 x 60	13.40	3.25	3.50	28.00	6.67	2.00	9.25	2.57	2.76	14.92	12.34
4	47,000	35 x 50		6.25	2.92	49.17	21.00						
3	50,000	45 x 35					23.00						
4	59,000	35 x 40		13.83	3.83	55.50							
Number of rows effect: P value (lsd 5%)			0.02 (4.2)	0.05 (3.5)	ns	0.007 (12.7)	0.002 (8.2)	ns		ns		0.01 (0.3)	
Effect of planting density within each row configuration: P value (spacing contrast)			ns	<0.001 (-0.3)	ns	<0.001 (-16.4)	0.03 (-0.5)	0.007 (2.2)		ns		ns	
Varietal effect: P value (lsd 5%)			ns	ns	ns	ns	ns	<0.001 (1.6)		ns		<0.001 (0.2)	
Interaction between variety and number of rows: P value (lsd 5%)			ns	ns	ns	ns	ns	ns		ns		ns	

Fresh weight of plant vegetation:

- Increasing planting density significantly decreased the vegetative vigour of plants in experiment 1, 2 and 3 (Table 27). In experiment 4 to 8 vegetative vigour was not significantly affected by increases in planting density.
- At 29,000 plants/ha vegetative vigour was generally the same or higher when plants were grown in a two row configuration instead of four (Table 27). An exception to this occurred in experiment 3 when the average fresh weight was 180 grams higher in plants grown in a four row configuration instead of two at 29,000 plants/ha.
- 'Aviron' produced significantly heavier fresh weights than 'Summer Love' at both 29,000 plants/ha and 39,000 plants/ha (Table 27). There was no significant difference in vegetative vigour between 'Granite' and 'Starlight' in experiment 8 and 'Monarch' and 'Moby' in experiment 6.

Table 27: Fresh weight of vegetative growth (grams) at 6 weeks after transplanting within crops grown at various planting densities and row configurations on a loam soil type.

Number of rows	Planting density (plants/ha)	Between row spacing x within row spacing (cm)	Experiment 1 Jun-Oct 04	Experiment 2 Nov 04-Jan 05	Experiment 3 Jan-Apr 05	Experiment 4 Apr-Jul 05	Experiment 5 Jun-Oct 05	Experiment 6 Nov 05-Feb 06		Experiment 7 Jan-Apr 06		Experiment 8 Apr-Aug 06	
			Virgin	Monarch	Summer Love	Brittany	Virgin	Monarch	Moby	Aviron	Summer Love	Granite	Starlight
2	29,000	80 x 40	1071.83	1318.07	1012.80	290.67	166.30	1163.27	1201.50	1228.23	1097.73	200.25	127.83
4	29,000	35 x 80	981.56	1126.70	1192.73	322.00	141.40	1297.27	1180.83	1030.47	970.40	218.25	141.13
4	34,000	35 x 70	923.42	1013.03	1206.50	288.00							
2	39,000	80 x 30											
3	39,000	45 x 45					126.17	1188.00	1308.97	1018.50	910.60	196.33	148.21
4	39,000	35 x 60	928.22	1053.30	1135.10	318.33	145.40	1314.20	1227.23	1114.30	1075.70	221.54	134.50
4	47,000	35 x 50		845.00	1133.70	279.27	145.77						
3	50,000	45 x 35					111.00						
4	59,000	35 x 40		766.10	1020.13	286.97							
Number of rows effect: P value (lsd 5%)			ns	<0.001 (134.3)	<0.001 (66.2)	ns	0.002 (29.0)	ns		<0.001 (55.5)		ns	
Effect of planting density within each row configuration: P value (spacing contrast)			0.008 (0.2)	<0.001 (173.4)	<0.001 (4.2)	ns	ns	ns		ns		ns	
Varietal effect: P value (lsd 5%)			ns	ns	ns	ns	ns	ns		<0.001 (45.3)		ns	
Interaction between variety and number of rows: P value (lsd 5%)			ns	ns	ns	ns	ns	ns		0.005 (64.1)		ns	

Cauliflower – Sandy soil

Total yield (tonnes per hectare)

- Increasing planting density significantly increased the total yield produced by plants in all experiments except for experiment 5 (Table 28). Generally the higher the planting density the greater the total yield achieved however an exception to this occurred in the fourth field trial where plants grown at a density of 39,000 plants/ha achieved the highest yield.
- Plants grown at 29,000 plants/ha produced the same total yield regardless of the number of rows used during experiment 1, 2, 5 (cv. Summer Love), 6 (cv. Aviron), 7 and 8 (Table 28). In experiment 3, 5 (cv. Fremont) and 6 (cv. Lisbon), total yield was observed to increase significantly when the row number was increased from 2 to either 3 or 4 rows per bed. Total yield decreased by 2.76 t/ha when the row number was increased from 2 to 4 in experiment 4. At 39,000 plants/ha the row configuration generally did not have a significant effect on total yield produced. Exceptions to this occurred in experiment 4 and 5 where plants grown in a 3 row configuration produced significantly higher total yields than plants grown in a 4 row configuration. In experiment 8 'Lisbon' plants produced significantly higher total yields when grown in 4 rows than in 3 and 'Aviron' plants produced 2.5 t/ha higher total yield when grown in 3 rows instead of 2.
- Varieties grown during the same seasonal period produced significantly different total yields (Table 28). During the winter period 'Sirente' was a significantly higher yielding variety than 'Amsterdam' at all planting densities. During the autumn period and at the lower planting density 'Aviron' was a higher yielding variety than 'Lisbon'. However during the spring period 'Lisbon' was generally higher yielding than 'Aviron' at both 29,000 plants/ha and 39,000 plants/ha. No significant difference in yielding potential was observed between 'Summer Love' and 'Fremont'.

Table 28: Total yield (t/ha) of cauliflower produced by crops grown at various planting densities and row configurations on a sandy soil type.

Number of rows	Planting density (plants/ha)	Between row spacing x within row spacing (cm)	Experiment 1 Nov 04-Feb 05	Experiment 2 Jan-Apr 05	Experiment 3 Apr-Jun 05	Experiment 4 Jul-Oct 05	Experiment 5 Nov 05-Jan 06		Experiment 6 Jan-Apr 06		Experiment 7 May-Jul 06		Experiment 8 Aug-Oct 06	
			Monarch	Summer Love	Monarch	Virgin	Summer Love	Fremont	Aviron	Lisbon	Amsterdam	Sirente	Aviron	Lisbon
2	29,000	80 x 40	20.75	20.28	19.17	25.58	18.97	15.61	23.10	19.70	21.53	24.52	22.40	24.47
3	29,000	45 x 60									22.13	22.76	24.48	24.78
4	29,000	35 x 80	20.65	22.02	21.46	22.82	18.80	20.24	25.00	22.50				
3	32,000	45 x 55				30.26								
4	34,000	35 x 70	20.64	23.17	22.00	25.76								
2	39,000	80 x 30									24.32	28.81	25.59	29.34
3	39,000	45 x 45				33.02	26.53	23.58	28.90	29.60	24.86	28.24	28.09	27.84
4	39,000	35 x 60	22.24	24.05	22.91	29.18	22.34	23.21	28.80	28.90	21.65	26.12	26.86	30.56
4	47,000	35 x 50	22.02	24.32	23.53	31.84								
3	50,000	45 x 35				31.48								
4	59,000	35 x 40	24.29	26.19	23.72									
Number of rows effect: P value (lsd 5%)			0.023 (2.3)	0.005 (2.5)	<0.001 (1.8)	<0.001 (2.2)	<0.001 (3.1)		<0.001 (2.0)		ns		0.010 (2.1)	
Effect of planting density within each row configuration: P value (spacing contrast)			0.004 (-0.09)	0.012 (-0.1)	0.008 (-0.6)	<0.001 (-0.03)	ns		0.002 (2.3)		<0.001 (2.6)		<0.001 (2.4)	
Varietal effect: P value (lsd 5%)			ns	ns	ns	ns	ns		0.02 (1.6)		<0.001 (1.7)		0.014 (1.5)	
Interaction between variety and number of rows: P value (lsd 5%)			ns	ns	ns	ns	ns		0.02 (3.2)		ns		ns	

Marketable Yield (tonnes per hectare) – Export market specifications

- During the first three field experiments, marketable yield was observed to decrease significantly with increasing planting density (Table 29). In experiment 5, 6 and 7 plants grown at a density of 29,000 and 39,000 plants/ha produced the same marketable yield. In experiment 4 and 8 marketable yield increased significantly with increasing density.
- Plants grown at 29,000 plants/ha produced the same marketable yield when grown in either a 2 or 4 row configuration (Table 29). An exception to this occurred in experiment 3 where plants grown in a 4 row configuration produced an extra 2.28 t/ha of marketable yield compared to plants grown in a 2 row configuration. At 39,000 plants/ha, plants grown in both a 3 and 4 row configuration produced the same marketable yield. 'Aviron' plants in experiment 8 produced an extra 3.76 t/ha of marketable yield when grown in 3 rows instead of 2.
- In experiment 6 varietal choice had no significant effect on the marketable yield produced at all planting densities and row configurations (Table 29). In experiment 5 'Summer Love' produced significantly higher marketable yields than 'Fremont'. In experiment 7 'Sirente' produced significantly higher marketable yields than 'Amsterdam' at all planting densities and row configurations. 'Lisbon' produced significantly higher marketable yields than 'Aviron' at all planting densities and row configurations in experiment 8.

Table 29: Marketable yield (t/ha) (export market specifications) of cauliflower produced by crops grown at various planting densities and row configurations on a sandy soil type.

Number of rows	Planting density (plants/ha)	Between row spacing x within row spacing (cm)	Experiment 1 Nov 04-Feb 05	Experiment 2 Jan-Apr 05	Experiment 3 Apr-Jun 05	Experiment 4 Jul-Oct 05	Experiment 5 Nov 05-Jan 06		Experiment 6 Jan-Apr 06		Experiment 7 May-Jul 06		Experiment 8 Aug-Oct 06	
			Monarch	Summer Love	Monarch	Virgin	Summer Love	Fremont	Aviron	Lisbon	Amsterdam	Sirente	Aviron	Lisbon
2	29,000	80 x 40	17.79	17.32	18.07	22.21	14.27	4.38	19.2	17.6	15.62	17.8	18.97	23.64
3	29,000	45 x 60									15.27	18.16	20.15	22.96
4	29,000	35 x 80	16.61	18.38	20.35	19.37	13.09	11.30	19.6	20.5				
3	32,000	45 x 55												
4	34,000	35 x 70	14.20	17.04	19.08	24.91								
2	39,000	80 x 30									13.79	19.55	20.93	27.21
3	39,000	45 x 45				24.18	18.53	11.63	20.5	26.8	13.71	17.59	24.69	25.61
4	39,000	35 x 60	14.80	15.88	17.67	24.69	14.13	9.20	22.5	25.2	12.27	17.82	21.3	28.21
4	47,000	35 x 50	9.64	15.77	12.00	23.94								
3	50,000	45 x 35				22.52								
4	59,000	35 x 40	8.11	8.64	7.58									
Number of rows effect: P value (lsd 5%)			0.023 (4.4)	ns	0.005 (1.8)	ns	ns		0.009 (3.0)		ns		ns	
Effect of planting density within each row configuration: P value (spacing contrast)			0.005 (0.2)	<0.001 (0.2)	<0.001 (0.3)	0.02 (-0.2)	ns		ns		ns		0.002 (2.4)	
Varietal effect: P value (lsd 5%)			ns	ns	ns	ns	0.001 (3.4)		ns		<0.001 (1.6)		<0.001 (1.5)	
Interaction between variety and number of rows: P value (lsd 5%)			ns	ns	ns	ns	ns		ns		ns		0.03 (2.9)	

Number of marketable curds per hectare suitable for domestic market specifications

- Increasing planting density significantly increased the number of marketable heads produced per hectare in all field experiments (Table 30).
- Alteration of the row configuration at 29,000 plants/ha did not have a significant effect on the number of marketable heads produced per hectare in experiment 1, 2, 3, 4, 6, 7 and 8 (Table 30). In experiment 5 increasing the number of rows at a planting density of 29,000 plants/ha resulted in an extra 5719 marketable ‘Fremont’ curds per hectare. At 39,000 plants/ha the number of marketable curds per hectare within crops of ‘Summer Love’ decreased by 4958 when the number of rows per bed was increased from 3 to 4. In experiment 7 at a planting density of 39,000 plants/ha increasing the number of rows per bed resulted in an extra 4117 marketable ‘Sirente’ curds per hectare.
- In experiment 5 there was no significant varietal difference in the number of marketable curds within crops of ‘Summer Love’ and ‘Fremont’ (Table 30). In experiment 6 and 8 there was a significant difference between varieties with ‘Lisbon’ producing significantly more marketable heads than ‘Aviron’ at both 29,000 plants/ha and 39,000 plants/ha. In experiment 7 there was no significant difference between ‘Amsterdam’ and ‘Sirente’ at a planting density of 29,000 plants/ha but at 39,000 plants/ha ‘Sirente’ produced significantly more marketable heads than ‘Amsterdam’.

Table 30: Number of marketable curds produced per hectare by crops grown at various planting densities and row configurations on a sandy soil type.

Number of rows	Planting density (plants/ha)	Between row spacing x within row spacing (cm)	Experiment 1 Nov 04-Feb 05	Experiment 2 Jan-Apr 05	Experiment 3 Apr-Jun 05	Experiment 4 Jul-Oct 05	Experiment 5 Nov 05-Jan 06		Experiment 6 Jan-Apr 06		Experiment 7 May-Jul 06		Experiment 8 Aug-Oct 06	
			Monarch	Summer Love	Monarch	Virgin	Summer Love	Fremont	Aviron	Lisbon	Amsterdam	Sirente	Aviron	Lisbon
2	29, 412	80 x 40	28900	28579	28902	28830	25647	19832	24060	27554	28824	27294	25647	28235
3	29, 412	45 x 60									26733	27204	25437	28617
4	29, 412	35 x 80	29035	27933	28574	28825	25003	25551	22904	28582				
3	32, 086	45 x 55				30497								
4	33, 613	35 x 70	32838	30969	31879	32997								
2	39, 216	80 x 30									30353	35176	33765	36471
3	39, 216	45 x 45				36708	36706	32178	29721	37165	29912	34270	33799	37214
4	39, 216	35 x 60	39027	36267	37845	38726	31748	30416	30440	35665	28758	31059	33150	36183
4	47, 059	35 x 50	45734	42857	41977	44865								
3	50, 420	45 x 35				47686								
4	58, 824	35 x 40	57483	51642	42547									
Number of rows effect: P value (lsd 5%)			<0.001 (1810)	<0.001 (3029)	<0.001 (2687)	<0.001 (4100)	<0.001 (2672)		<0.001 (1724)		ns		0.001 (1960)	
Effect of planting density within each row configuration: P value (spacing contrast)			<0.001 (-705)	<0.001 (-547)	<0.001 (-387)	0.001 (-391)	<0.001 (3086)		<0.001 (1990)		<0.001 (2809)		<0.001 (2264)	
Varietal effect: P value (lsd 5%)			ns	ns	ns	ns	ns		<0.001 (1407)		0.02 (1777)		<0.001 (1432)	
Interaction between variety and number of rows: P value (lsd 5%)			ns	ns	ns	ns	<0.001 (3779)		0.02 (2438)		0.04 (3973)		ns	

Average curd weight (grams)

- Increasing planting density significantly decreased the average weight of curds for all varieties and seasonal periods assessed (Table 31). The exception to this was ‘Lisbon’ plants (experiment 6) where the average weight of curds remained the same when planting density was increased from 29,000 plants/ha to 39,000 plants/ha.
- The row configuration used at 29,000 plants/ha and 39,000 plants/ha generally did not have a significant effect on the average weight of curds (Table 31). An exception to this occurred in experiment 3 where the average weight of curds produced by plants grown at 29,000 plants/ha decreased by 65.19 g when the row configuration was altered from 2 to 4 rows. In experiment 4 the average weight of curds increased 108.39 g when the number of rows was increased from 3 to 4.
- There was no significant varietal effect during the summer (experiment 5) and autumn (experiment 6) of year 2 (Table 31). ‘Sirente’ produced significantly heavier curds than ‘Amsterdam’ at all planting densities. During the spring experiment, ‘Lisbon’ produced significantly heavier curds than ‘Aviron’ at both 29,000 plants/ha and 39,000 plants/ha.

Table 31: Average weight of curds (g) produced by cauliflower crops grown at various planting densities and row configurations on a sandy soil type.

Number of rows	Planting density (plants/ha)	Between row spacing x within row spacing (cm)	Experiment 1 Nov 04-Feb 05	Experiment 2 Jan-Apr 05	Experiment 3 Apr-Jun 05	Experiment 4 Jul-Oct 05	Experiment 5 Nov 05-Jan 06		Experiment 6 Jan-Apr 06		Experiment 7 May-Jul 06		Experiment 8 Aug-Oct 06	
			Monarch	Summer Love	Monarch	Virgin	Summer Love	Fremont	Aviron	Lisbon	Amsterdam	Sirente	Aviron	Lisbon
2	29,000	80 x 40	730.37	689.26	765.11	906.63	651.71	469.05	868.20	753.60	665.03	821.30	782.90	835.95
3	29,000	45 x 60									684.51	783.66	832.54	823.74
4	29,000	35 x 80	686.36	653.59	699.92	936.87	674.99	642.08	786.20	771.30				
3	32,000	45 x 55				921.37								
4	34,000	35 x 70	614.69	579.34	662.94	975.16								
2	39,000	80 x 30									600.76	714.31	652.21	750.90
3	39,000	45 x 45				834.49	584.04	566.52	725.90	727.80	622.67	681.40	748.39	717.58
4	39,000	35 x 60	629.31	527.61	583.05	942.88	568.77	524.06	717.20	729.50	601.97	717.36	663.90	817.29
4	47,000	35 x 50	472.87	517.33	478.11	850.42								
3	50,000	45 x 35				627.74								
4	59,000	35 x 40	405.28	411.83	399.65									
Number of rows effect: P value (lsd 5%)			0.004 (54.6)	<0.001 (46)	<0.001 (29)	<0.001 (79.8)	ns		ns		ns		ns	
Effect of planting density within each row configuration: P value (spacing contrast)			0.006 (2.6)	<0.001 (6)	<0.001 (8)	<0.001 (14.7)	0.04 (103.8)		0.01 (68.1)		0.002 (59.6)		<0.001 (57.8)	
Varietal effect: P value (lsd 5%)			ns	ns	ns	ns	ns		ns		<0.001 (37.7)		0.006 (35.6)	
Interaction between variety and number of rows: P value (lsd 5%)			ns	ns	ns	ns	ns		ns		ns		0.003 (70.8)	

Average curd size (diameter (cm))

- The average size of curds was not significantly affected by increasing planting density for the majority of field experiments (Table 32). During experiment 1, 2 and 8 the average size of curds was observed to decrease significantly as planting density increased.

- Average curd size was not significantly affected by alteration of row configuration at 29,000 plants/ha and 39,000 plants/ha for all field experiments (Table 32).
- Variety of cauliflower did not significantly affect the average size of curds except in experiment 7 where ‘Sirente’ plants grown at a planting density of 39,000 plants/ha in a 4 row configuration produced significantly larger curds than ‘Amsterdam’ (Table 32).

Table 32: Average size of curds (cm) produced by cauliflower crops grown at various planting densities and row configurations on a sandy soil type.

Number of rows	Planting density (plants/ha)	Between row spacing x within row spacing (cm)	Experiment 1 Nov 04-Feb 05	Experiment 2 Jan-Apr 05	Experiment 3 Apr-Jun 05	Experiment 4 Jul-Oct 05	Experiment 5 Nov 05-Jan 06		Experiment 6 Jan-Apr 06		Experiment 7 May-Jul 06		Experiment 8 Aug-Oct 06	
			Monarch	Summer Love	Monarch	Virgin	Summer Love	Fremont	Aviron	Lisbon	Amsterdam	Sirente	Aviron	Lisbon
2	29,000	80 x 40	13.90	15.00	14.09	15.62	14.70	13.30	16.3	15.4	15.80	16.20	15.50	15.80
3	29,000	45 x 60									15.90	16.20	15.80	15.30
4	29,000	35 x 80	13.64	15.20	16.29	15.66	14.60	15.10	15.9	15.4				
3	32,000	45 x 55				15.66								
4	34,000	35 x 70	12.98	14.20	13.43	15.94								
2	39,000	80 x 30									15.50	15.90	14.80	14.70
3	39,000	45 x 45				15.71	13.90	14.40	15.6	16.7	15.30	15.50	15.60	14.40
4	39,000	35 x 60	13.06	14.00	17.06	15.77	13.60	14.70	15.7	15.6	15.40	17.00	14.80	15.10
4	47,000	35 x 50	11.73	13.70	12.29	15.31								
3	50,000	45 x 35				14.09								
4	59,000	35 x 40	11.11	12.70	11.81									
Number of rows effect: P value (lsd 5%)			0.002 (0.4)	0.002 (0.6)	ns	ns	ns		ns		ns		ns	
Effect of planting density within each row configuration: P value (spacing contrast)			0.003 (0.02)	<0.001 (0.6)	ns	ns	ns		ns		ns		0.003 (0.6)	
Varietal effect: P value (lsd 5%)			ns	ns	ns	ns	ns		ns		0.04 (0.5)		ns	
Interaction between variety and number of rows: P value (lsd 5%)			ns	ns	ns	ns	0.03 (0.1)		0.01 (0.9)		ns		ns	

Uniformity of curd weight: **Percentage of curds within crop that weigh between 0.9 kg and 1.1 kg**

- Uniformity of curd weight decreased significantly with increasing planting density during experiment 1, 2, 3, 4 and 8 (Table 33). However during experiments 5, 6 and 7 increasing planting density from 29,000 plants/ha to 39,000 plants/ha did not significantly effect the uniformity of curd weight.
- During experiments 1, 2 and 3, increasing the number of rows from 2 to 4 at a planting density of 29,000 plants/ha resulted in a significant decrease in the uniformity of curd weight (Table 33). In experiments 4, 5, 6, 7 and 8 there was no significant difference in the percentage of curds within the crop weighing 1.0 kg when the row configuration was altered at a planting density of 29,000 plants/ha and 39,000 plants/ha.
- During experiment 5 ‘Summer Love’ produced a significantly higher percentage of curds which weighed approximately 1.0 kg than ‘Fremont’ at all planting densities (Table 33). During experiment 7, ‘Sirente’ crops had a significantly higher percentage of curds which weighed approximately 1.0 kg than ‘Amsterdam’ at all planting densities. During experiment 6 and 8 there was no varietal effect on the uniformity of curd weight within crops.

Table 33: Uniformity of curd weight (percentage of curds which weigh between 0.9 kg and 1.1 kg) within cauliflower crops grown at various planting densities and row configurations on a sandy soil type.

Number of rows	Planting density (plants/ha)	Between row spacing x within row spacing (cm)	Experiment 1 Nov 04-Feb 05	Experiment 2 Jan-Apr 05	Experiment 3 Apr-Jun 05	Experiment 4 Jul-Oct 05	Experiment 5 Nov 05-Jan 06		Experiment 6 Jan-Apr 06		Experiment 7 May-Jul 06		Experiment 8 Aug-Oct 06	
			Monarch	Summer Love	Monarch	Virgin	Summer Love	Fremont	Aviron	Lisbon	Amsterdam	Sirente	Aviron	Lisbon
2	29,000	80 x 40	13.67	13.35	16.09	21.55	12.67	1.49	15.02	19.20	6.07	22.37	17.44	21.34
3	29,000	45 x 60									6.81	16.59	21.18	21.18
4	29,000	35 x 80	7.51	8.63	8.37	24.63	11.47	5.30	16.09	21.62				
3	32,000	45 x 55				16.71								
4	34,000	35 x 70	5.58	7.61	6.25	23.44								
2	39,000	80 x 30									2.32	13.14	13.73	14.19
3	39,000	45 x 45				17.55	5.80	4.57	15.66	11.29	5.37	13.28	17.39	13.04
4	39,000	35 x 60	2.93	1.92	3.22	24.61	9.74	0.74	14.73	14.88	4.55	15.15	13.98	19.03
4	47,000	35 x 50	0.98	2.83	1.83	19.40								
3	50,000	45 x 35				9.44								
4	59,000	35 x 40	0.98	0.00	0.85									
Number of rows effect: P value (lsd 5%)			<0.001 (2.9)	<0.001 (3.3)	<0.001 (4.6)	0.005 (7.1)	ns		ns		ns		ns	
Effect of planting density within each row configuration: P value (spacing contrast)			<0.001 (0.2)	<0.001 (0.2)	<0.001 (0.2)	0.03 (0.4)	ns		ns		ns		0.016 (5.4)	
Varietal effect: P value (lsd 5%)			ns	ns	ns	ns	0.005 (4.7)		ns		<0.001 (6.8)		ns	
Interaction between variety and number of rows: P value (lsd 5%)			ns	ns	ns	ns	ns		ns		ns		ns	

Uniformity of curd maturation: Number of harvests

- The uniformity of curd maturation was not significantly affected by increasing planting density with the number of harvests required to remove the crop remaining the same during all field experiments (Table 34). The exception to this was experiment 1 where the number of harvests required was observed to increase with increasing planting density.
- Changing the row configuration did not significantly affect the uniformity of curd maturation except during experiment 5 (Table 34). ‘Summer Love’ plants grown at 29,000 plants/ha required significantly less harvests when the number of rows per bed was increased from 2 to 4.
- Variety had a significant affect on the uniformity of maturation in experiment 5 with ‘Fremont’ plants requiring significantly less harvests than ‘Summer Love’ at all planting densities (Table 34). In experiment 7 ‘Sirente’ required significantly less picks than ‘Amsterdam’ at all planting densities and row configurations. There was no significant difference in the number of harvests required for varieties assessed in experiment 6 and 8.

Table 34: Uniformity of curd maturation (number of harvests) within cauliflower crops grown at various planting densities and row configurations on a sandy soil type.

Number of rows	Planting density (plants/ha)	Between row spacing x within row spacing (cm)	Experiment 1 Nov 04-Feb 05	Experiment 2 Jan-Apr 05	Experiment 3 Apr-Jun 05	Experiment 4 Jul-Oct 05	Experiment 5 Nov 05-Jan 06		Experiment 6 Jan-Apr 06		Experiment 7 May-Jul 06		Experiment 8 Aug-Oct 06	
			Monarch	Summer Love	Monarch	Virgin	Summer Love	Fremont	Aviron	Lisbon	Amsterdam	Sirente	Aviron	Lisbon
2	29,000	80 x 40	5.80	7.00	6.80	2.00	2.40	1.40	2.60	2.60	3.00	2.20	2.60	2.60
3	29,000	45 x 60									2.60	2.20	2.40	2.80
4	29,000	35 x 80	4.20	7.00	7.20	2.00	3.00	1.00	2.60	2.80				
3	32,000	45 x 55				2.00								
4	34,000	35 x 70	6.20	7.00	7.60	1.60								
2	39,000	80 x 30									3.20	2.20	3.00	2.60
3	39,000	45 x 45				2.00	2.60	1.20	2.80	2.60	2.80	2.20	2.60	2.20
4	39,000	35 x 60	6.00	7.00	7.60	1.80	2.60	1.00	2.80	2.80	3.00	2.60	2.80	2.20
4	47,000	35 x 50	6.25	7.00	7.20	1.80								
3	50,000	45 x 35				1.80								
4	59,000	35 x 40	6.60	7.00	7.40									
Number of rows effect: P value (lsd 5%)			ns	ns	ns	ns	ns		ns		ns		ns	
Effect of planting density within each row configuration: P value (spacing contrast)			0.003 (-0.05)	ns	ns	ns	ns		ns		ns		ns	
Varietal effect: P value (lsd 5%)			ns	ns	ns	ns	<0.001 (0.3)		ns		<0.001 (0.3)		ns	
Interaction between variety and number of rows: P value (lsd 5%)			ns	ns	ns	ns	0.04 (0.4)		ns		ns		ns	

Uniformity of curd maturation: Percentage of total yield removed at each harvest

Experiment 1: Plants grown at 29,000 plants/ha in a 4 row configuration matured earlier than plants at other planting densities and row configurations with a higher percentage of total yield removed at the first harvest (Figure 5). In all other row configurations and planting densities similar percentages of the crop were removed at each harvest.

Experiment 2, 3, 4 and 6: Plants grown in all row configurations and planting densities appear to have matured at approximately the same times with similar percentages of the crop removed at each harvest (Figure 5).

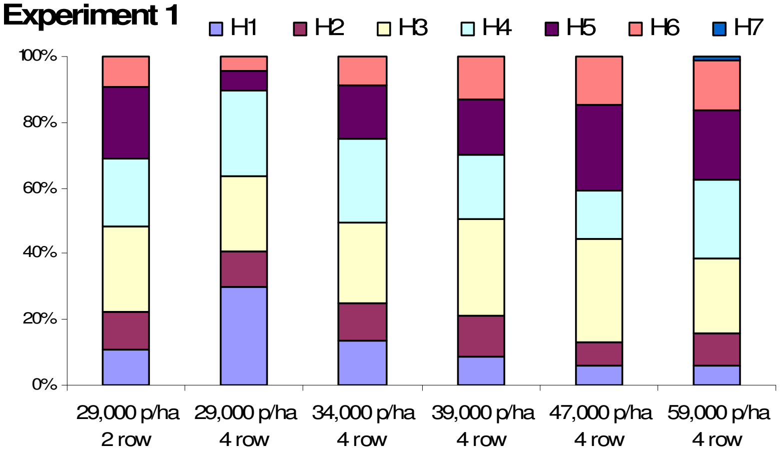
Experiment 5: 'Summer Love' plants grown at 39,000 plants/ha in a 4 row configuration were slightly less uniform, requiring four harvests compared to three for plants in other row configurations and planting densities (Figure 5). Plants grown in a 4 row configuration at 29,000 plants/ha matured earliest. 'Fremont' plants grown in a four row configuration at both 29,000 plants/ha and 39,000 plants/ha were the most uniform requiring only 1 harvest compared to those grown in a 2 and 3 row configuration which required 2 harvests. 'Fremont' plants matured more uniformly than 'Summer Love'.

Experiment 7: 'Amsterdam' and 'Sirente' plants grown in a 3 row configuration at 29,000 plants/ha matured earlier than plants in all other row configurations and planting densities (Figure 5). However 'Sirente' plants were also less uniform in this row configuration requiring an extra 3 harvests.

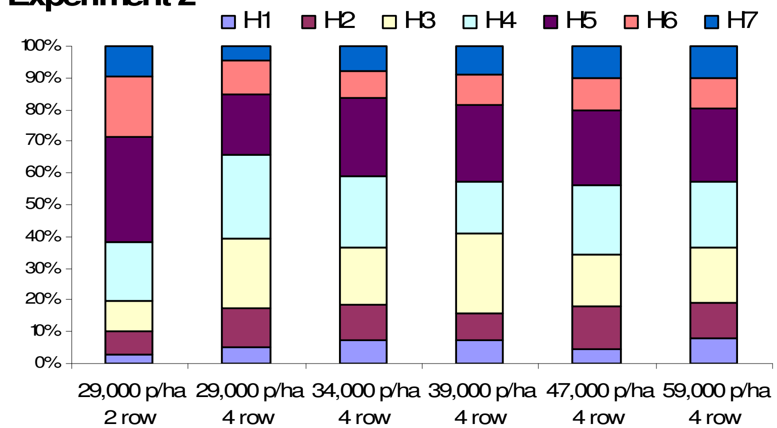
Experiment 8: 'Aviron' plants in a 3 row configuration at 29,000 plants/ha matured slightly earlier than plants grown at 39,000 plants/ha with a higher percentage of crop removed at first harvest (Figure 5). 'Lisbon' plants grown in all row configurations and planting densities appear to have matured at approximately the same time with similar percentages of the crop removed at each harvest.

In general there was a slight trend for plants grown at 29,000 plants/ha in a three or four row configuration to mature earlier than plants at the same density in a 2 row configuration or those grown at higher planting densities. There were no major differences observed in the uniformity of maturity between plants in the majority of row configurations and planting densities assessed.

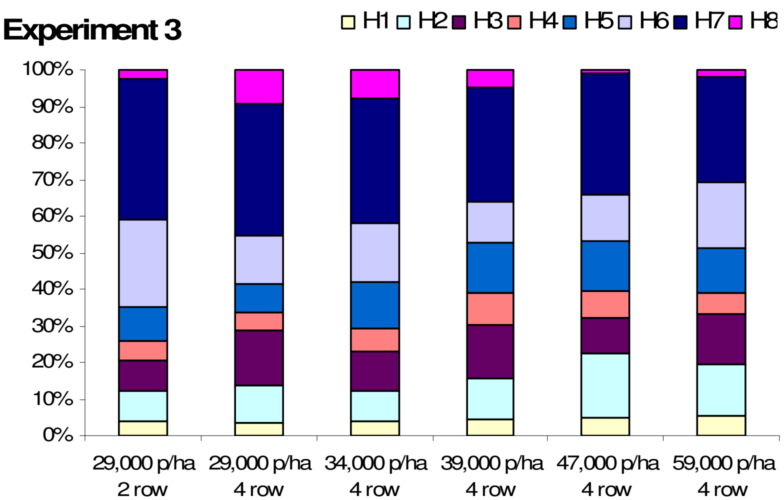
Experiment 1



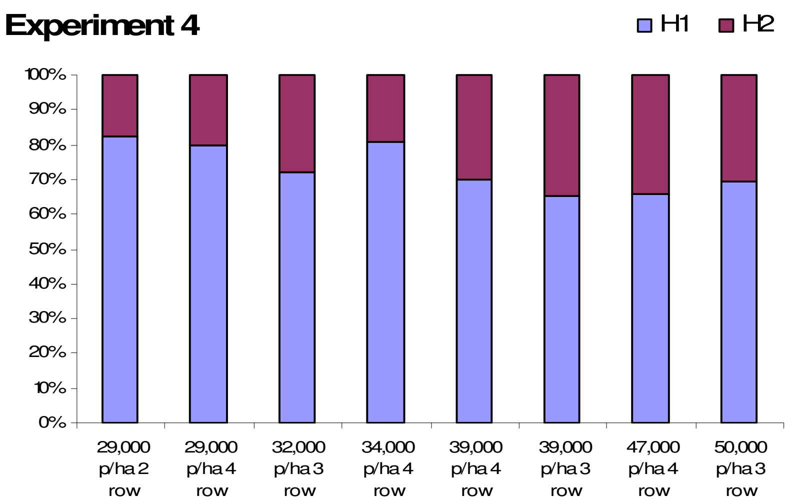
Experiment 2



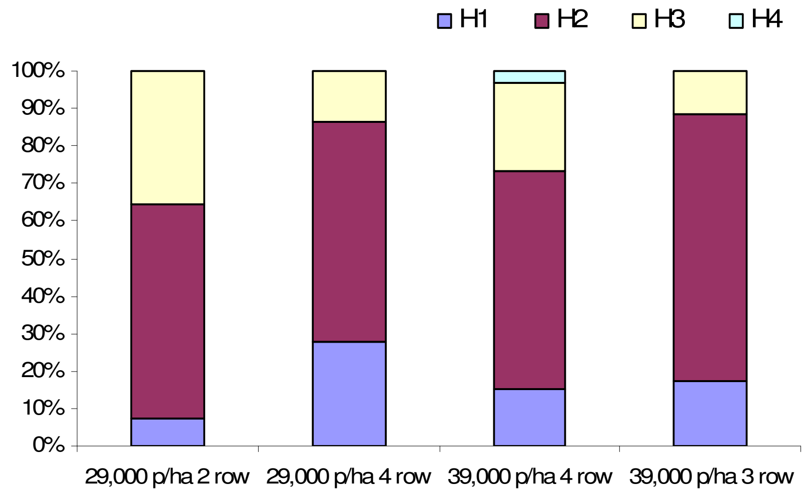
Experiment 3



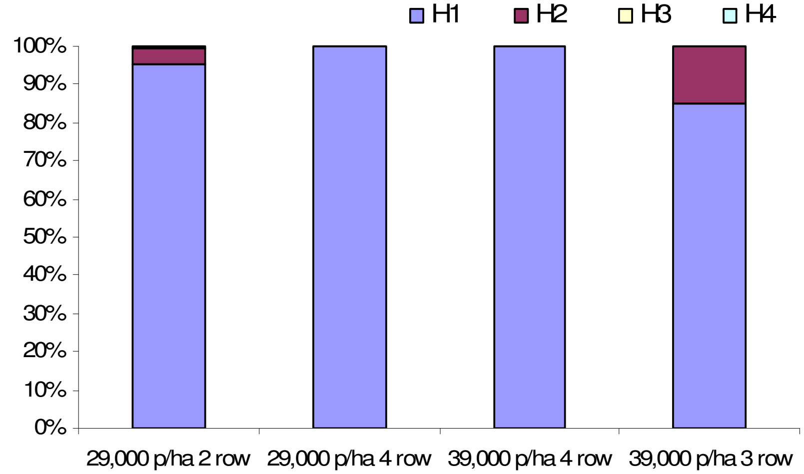
Experiment 4



Summer Love - Experiment 5

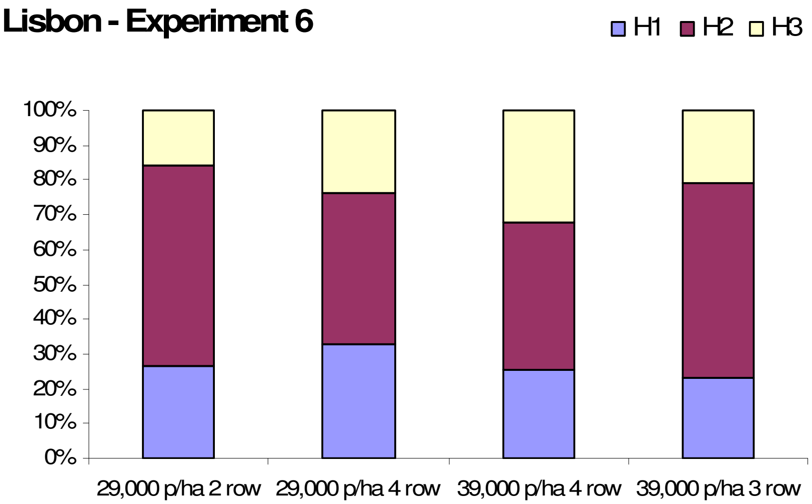


Fremont - Experiment 5



Aviron - Experiment 6

Lisbon - Experiment 6



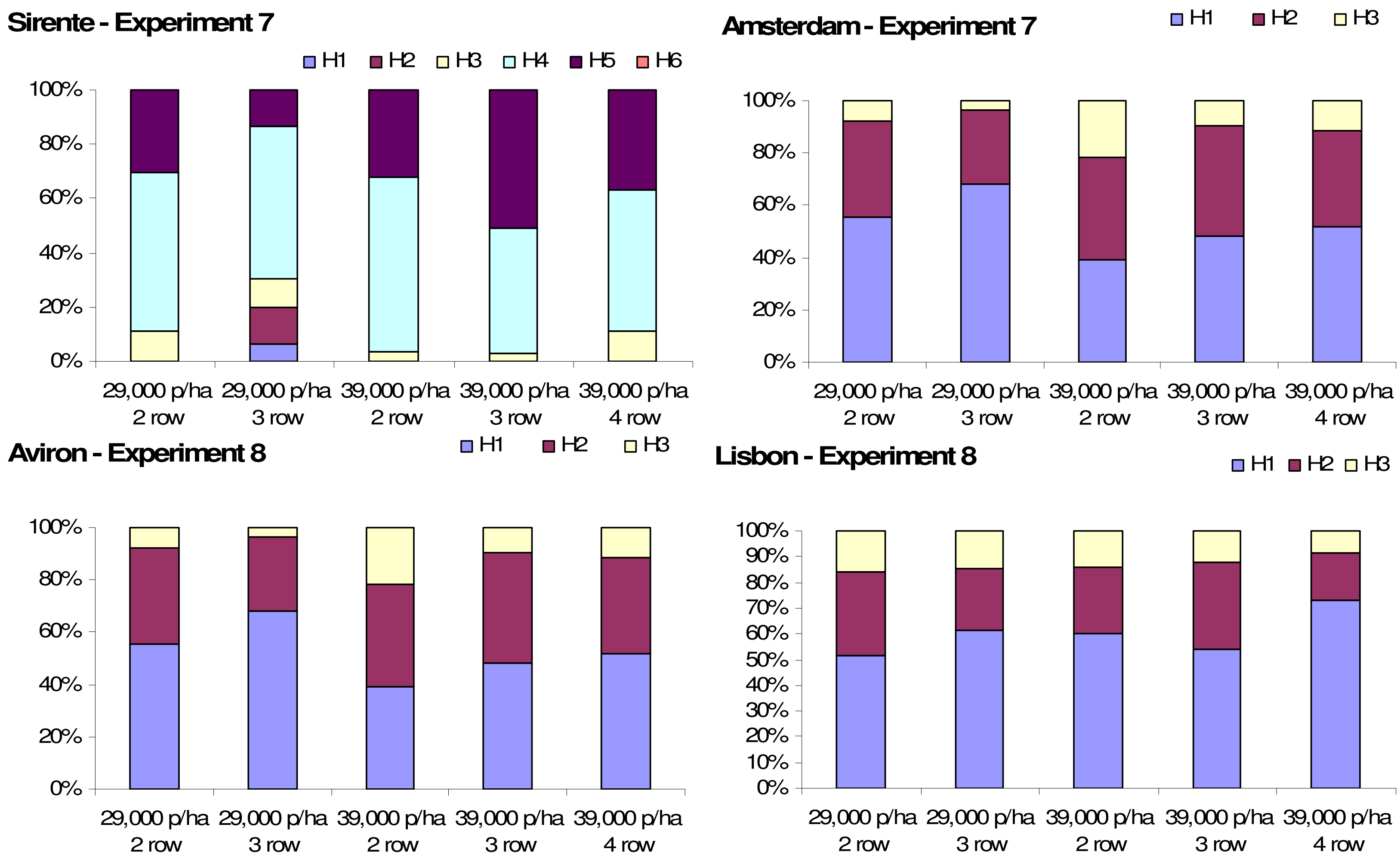


Figure 5: Percentage of total yield (t/ha) removed at each harvest during eight field experiments conducted at the sandy soil site.

Rejection reasons

The two primary reasons why cauliflower curds were not considered acceptable for market specifications was reduced curd weight (less than 500g) and yellowing (discolouration of curds due to sun exposure).

'Too Small' (percentage of curds within the crop which weigh below 500 g)

- Increasing planting density significantly increased the number of curds within the crop which weighed below 500g during experiment 1, 2, 3, 4, 5 and 7 (Table 35). During experiment 6 and 8 there was no significant difference in the percentage of 'too small' curds within the crop when plants were grown at either 29,000 plants/ha or 39,000 plants/ha.
- Alteration of the row configuration at 29,000 plants/ha and 39,000 plants/ha had no significant effect on the percentage of curds within the crop which weighed below 500 g (Table 35).
- There was no varietal effect on the percentage of 'too small' curds within the crop during experiment 5 and 6 (Table 35). In experiment 7 'Amsterdam' plants had significantly more small curds than 'Sirente' at a planting density of 39,000 plants/ha. In experiment 8 'Aviron' had significantly more 'too small' curds than 'Lisbon' when grown in a 2 and 4 row configuration at both 29,000 plants/ha and 39,000 plants/ha.

Table 35: Percentage of 'too small' curds (below 500 g) within cauliflower crops grown at various planting densities and row configurations on a sandy soil type.

Number of rows	Planting density (plants/ha)	Between row spacing x within row spacing (cm)	Experiment 1 Nov 04-Feb 05	Experiment 2 Jan-Apr 05	Experiment 3 Apr-Jun 05	Experiment 4 Jul-Oct 05	Experiment 5 Nov 05-Jan 06		Experiment 6 Jan-Apr 06		Experiment 7 May-Jul 06		Experiment 8 Aug-Oct 06	
			Monarch	Summer Love	Monarch	Virgin	Summer Love	Fremont	Aviron	Lisbon	Amsterdam	Sirente	Aviron	Lisbon
2	29,000	80 x 40	10.00	21.00	5.67	3.90	28.00	57.20	5.71	10.78	10.60	7.11	12.87	6.41
3	29,000	45 x 60									10.76	5.66	8.14	5.73
4	29,000	35 x 80	16.00	24.67	8.00	4.21	21.07	15.00	9.94	11.56				
3	32,000	45 x 55				3.61								
4	34,000	35 x 70	27.35	40.58	16.52	6.19								
2	39,000	80 x 30									18.28	10.74	18.47	9.01
3	39,000	45 x 45				7.44	31.94	28.66	14.38	4.95	23.34	15.13	11.59	11.03
4	39,000	35 x 60	34.50	42.25	26.25	3.69	40.27	40.27	14.82	8.49	22.35	10.50	17.43	6.42
4	47,000	35 x 50	58.85	42.19	59.79	9.33								
3	50,000	45 x 35				24.37								
4	59,000	35 x 40	75.67	69.67	71.67									
Number of rows effect: P value (lsd 5%)			<0.001 (8.0)	0.002 (13.0)	<0.001 (12.3)	0.003 (5.3)	ns		ns		ns		ns	
Effect of planting density within each row configuration: P value (spacing contrast)			<0.001 (-1.5)	<0.001 (-1.0)	<0.001 (-0.9)	0.001 (-1.0)	0.008 (15.9)		ns		0.019 (8.5)		ns	
Varietal effect: P value (lsd 5%)			ns	ns	ns	ns	ns		ns		0.009 (5.3)		<0.001 (3.2)	
Interaction between variety and number of rows: P value (lsd 5%)			ns	ns	ns	ns	ns		ns		ns		ns	

‘Yellowing’ (percentage of yellow curds within the crop)

- Increasing planting density had no significant effect on the percentage of yellow curds within the crop (Table 36). The exception to this occurred in experiment 1 where increasing planting density from 29,000 plants/ha to 59,000 plants/ha decreased the percentage of yellow curds within the crop by 15%.
- Alteration of the row configuration had no significant effect on the percentage of yellow curds within the crop (Table 36). The exception to this occurred in experiment 2 where increasing the number of rows from 2 to 4 in crops planted at a density of 29,000 plants/ha increased the percentage of yellow curds within the crop by 7.33%.
- There was no significant varietal effect observed in experiment 7 and 8 (Table 36). In experiment 5 and 6 there was no significant varietal effect when plants were grown in a 2 row configuration. However ‘Fremont’ had significantly more yellow curds than ‘Summer Love’ when grown in a 3 and 4 row configuration and ‘Lisbon’ had significantly more yellow curds than ‘Aviron’ when grown in a 4 row configuration.

Table 36: Percentage of yellow curds within cauliflower crops grown at various planting densities and row configurations on a sandy soil type.

Number of rows	Planting density (plants/ha)	Between row spacing x within row spacing (cm)	Experiment 1 Nov 04-Feb 05	Experiment 2 Jan-Apr 05	Experiment 3 Apr-Jun 05	Experiment 4 Jul-Oct 05	Experiment 5 Nov 05-Jan 06		Experiment 6 Jan-Apr 06		Experiment 7 May-Jul 06		Experiment 8 Aug-Oct 06	
			Monarch	Summer Love	Monarch	Virgin	Summer Love	Fremont	Aviron	Lisbon	Amsterdam	Sirente	Aviron	Lisbon
2	29,000	80 x 40	16.00	4.67	5.33	18.66	14.00	20.80	3.05	5.10	12.29	9.03	14.75	18.06
3	29,000	45 x 60									11.61	9.18	17.59	18.17
4	29,000	35 x 80	26.00	12.00	4.33	15.38	12.50	22.50	1.66	7.22				
3	32,000	45 x 55				21.26								
4	34,000	35 x 70	20.00	11.30	6.38	26.18								
2	39,000	80 x 30									15.60	9.37	11.40	17.79
3	39,000	45 x 45				26.78	13.13	28.06	2.93	3.18	17.12	15.01	16.83	17.30
4	39,000	35 x 60	25.00	9.75	12.25	25.00	10.13	21.07	3.40	8.39	10.48	10.56	15.97	21.45
4	47,000	35 x 50	15.36	11.72	7.50	21.41								
3	50,000	45 x 35				19.03								
4	59,000	35 x 40	11.00	6.67	6.67									
Number of rows effect: P value (lsd 5%)			ns	0.032 (5.1)	0.02 (4.7)	ns	ns		ns		ns		ns	
Effect of planting density within each row configuration: P value (spacing contrast)			0.03 (0.4)	ns	ns	ns	ns		ns		ns		ns	
Varietal effect: P value (lsd 5%)			ns	ns	ns	ns	0.01 (7.9)		0.012 (2.5)		ns		ns	
Interaction between variety and number of rows: P value (lsd 5%)			ns	ns	ns	ns	ns		ns		ns		ns	

Fresh weight of plant vegetation:

- Increasing planting density significantly decreased the fresh weight of plants in experiment 1, 2 and 3 (Table 37).
- In experiment 5 ‘Fremont’ plants grown at 29,000 plants/ha produced an extra 69 g of fresh weight when grown in 4 rows instead of 2. At 39,000 plants/ha, the fresh weight of ‘Fremont’ and ‘Summer Love’ plants significantly decreased when grown in 4 rows

instead of 3. In experiment 6 'Lisbon' plants grown at 29,000 plants/ha produced heavier fresh weights when grown in 4 rows instead of 2 rows (Table 37).

- A significant difference was observed in the level of vegetative vigour between varieties (Table 37). In experiment 6 'Lisbon' plants were significantly more vigorous than 'Aviron' however in experiment 8 the reverse occurred. In experiment 7 'Amsterdam' produced more vigorous plants than 'Sirente' and in experiment 5 'Fremont' produced higher fresh weight levels than 'Summer Love'.

Table 37: Fresh weight of vegetative growth (grams) of cauliflower plants grown at various planting densities and row configurations on a sandy soil type.

Number of rows	Planting density (plants/ha)	Between row spacing x within row spacing (cm)	Experiment 1 Nov 04-Feb 05	Experiment 2 Jan-Apr 05	Experiment 3 Apr-Jun 05	Experiment 4 Jul-Oct 05	Experiment 5 Nov 05-Jan 06		Experiment 6 Jan-Apr 06		Experiment 7 May-Jul 06		Experiment 8 Aug-Oct 06	
			Monarch	Summer Love	Monarch	Virgin	Summer Love	Fremont	Aviron	Lisbon	Amsterdam	Sirente	Aviron	Lisbon
2	29,000	80 x 40	1199.67	698.89	573.33	340.83	388.30	419.40	849.13	958.67	228.33	210.27	307.37	250.57
3	29,000	45 x 60											317.80	257.80
4	29,000	35 x 80	1466.95	856.90	579.25	328.03	368.10	488.40	930.10	1116.07				
3	32,000	45 x 55				345.07								
4	34,000	35 x 70	1314.30	799.10	617.78	362.90								
2	39,000	80 x 30									229.37	217.97	314.13	248.80
3	39,000	45 x 45				333.14	465.87	573.87	881.87	1101.40	213.97	213.57	295.50	265.57
4	39,000	35 x 60	1218.17	750.62	595.06	333.70	399.37	496.00	928.17	1190.93	222.17	217.33	322.83	276.43
4	47,000	35 x 50	1140.92	741.52	538.28	346.72								
3	50,000	45 x 35				320.09					228.87	201.77		
4	59,000	35 x 40	927.70	669.38	474.78									
Number of rows effect: P value (lsd 5%)			ns	0.04	ns	ns	<0.001 (41.7)		0.047 (107.8)		ns		ns	
Effect of planting density within each row configuration: P value (spacing contrast)			<0.001 (13.0)	<0.001 (4.0)	0.012 (3.5)	ns	ns		ns		ns		ns	
Varietal effect: P value (lsd 5%)			ns	ns	ns	ns	<0.001 (34.0)		<0.001 (88.0)		0.015 (9.8)		<0.001 (14.2)	
Interaction between variety and number of rows: P value (lsd 5%)			ns	ns	ns	ns	ns		ns		ns		ns	

Nutrient Program – Loam and sandy soil site:

Leaf tissue analysis during field experiments revealed the fertiliser program developed for this project could be further modified for commercial practice. The levels of N, P and K were increased during field experimentation to ensure that plants grown at the higher planting densities were not nutritionally limited. Leaf tissue analysis revealed that N, P and K were at high levels within leaves for the majority of field experiments indicating the application rate of these elements could probably be lowered. Care should be taken to ensure plant growth does not become limited by a lack of major nutrients prior to harvest. The majority of leaf tissue analysis conducted for this project occurred at an early stage of crop development (six weeks after transplanting), therefore although nutrient levels were high early during crop development it is likely that nutrient levels would reduce as the crop matured. It was also noted from the leaf tissue analysis the level of trace elements should be carefully monitored as calcium, boron and manganese were often found to be at low levels within leaf tissue. For commercial practice, it would be strongly recommended to increase the application rate of these trace elements when growing plants at increased planting densities. Regular testing of nutrient levels within the plant will assist in the development of a suitable fertiliser program for crops grown commercially at increased planting densities. Sampling of leaves should occur at both an early and late stage of crop development to determine the best rate and time to apply nutrients.

Broccoli – Loam soil

Total Yield (tonnes per hectare)

- Increasing planting density did not significantly increase total yield in experiment 1, 2 and 3 (Table 38). In experiment 4 total yield of 'Viper' increased significantly with increasing planting density.
- In experiment 1 and 3, there was no significant difference in the total yield of plants grown in either a 3 or 4 row configuration at a planting density of 59,000 plants/ha (Table 38). In experiment 2, plants grown at a planting density of 59,000 plants/ha in a 4 row configuration produced an extra 2.1 t/ha of total yield compared to the yield from plants grown in a 3 row configuration.

Table 38: Total yield (t/ha) of broccoli crops grown at various planting densities and row configurations on a loam soil type.

Number of rows	Planting density (plants/ha)	Between row spacing x within row spacing (cm)	Experiment 1 Nov 05– Feb 06	Experiment 2 Jan – Apr 06	Experiment 3 Apr – Aug 06	Experiment 4 Dec 06– Feb 07
			Viper	Viper	Ironman	Viper
2	39,000	80 x 30				16.76
3	44,000	45 x 40	16.71	11.7	14.07	19.61
4	47,000	35 x 50	18.14	14.9	16.26	
2	51,000	80 x 23				20.64
4	52,000	35 x 45				19.19
3	59,000	45 x 30	17.37	12.3	14.67	18.69
4	59,000	35 x 40	16.85	14.4	14.87	
4	69,000	35 x 34				21.23
Effect of number of rows: P value (lsd 5%)			ns	0.02 (1.9)	ns	ns
Effect of planting density within each row configuration: P value (lsd 5%)			ns	ns	ns	0.02 (2.6)
P value and linear spacing contrast within 3 row configuration			ns	ns	ns	ns
P value and linear spacing contrast within 4 row configuration			ns	ns	ns	ns

Marketable Yield – Export market specifications (tonnes per hectare)

- Increasing planting density did not significantly increase marketable yield in experiment 1, 2 and 3 (Table 39). In experiment 4, marketable yield of 'Viper' increased significantly with increasing planting density.
- In experiment 1 and 3 there was no significant difference in the marketable yield of plants grown in either a 3 or 4 row configuration at a planting density of 59,000 plants/ha (Table 39). In experiment 2, plants grown at a planting density of 59,000 plants/ha in a 4 row configuration produced an additional 2.2 t/ha of marketable yield compared to plants grown in a 3 row configuration.

Table 39: Marketable yield – export market specifications (t/ha) of broccoli crops grown at various planting densities and row configurations on a loam soil type.

Number of rows	Planting density (plants/ha)	Between row spacing x within row spacing (cm)	Experiment 1 Nov 05 – Feb 06	Experiment 2 Jan – Apr 06	Experiment 3 Apr – Aug 06	Experiment 4 Dec 06 – Feb 07
			Viper	Viper	Ironman	Viper
2	39,000	80 x 30				12.52
3	44,000	45 x 40	12.36	11.16	9.62	14.26
4	47,000	35 x 50	12.03	14.36	10.45	
2	51,000	80 x 23				18.18
4	52,000	35 x 45				17.25
3	59,000	45 x 30	15.61	11.76	11.23	16.91
4	59,000	35 x 40	12.90	13.96	10.29	
4	69,000	35 x 34				18.95
Effect of number of rows: P value (lsd 5%)			ns	0.03 (2.1)	ns	ns
Effect of planting density within each row configuration: P value (lsd 5%)			ns	ns	ns	0.02 (3.7)
P value and linear spacing contrast within 3 row configuration			ns	ns	ns	ns
P value and linear spacing contrast within 4 row configuration			ns	ns	ns	0.04 (-0.2)

Number of marketable heads produced per hectare – domestic market specifications

- In experiment 1 increasing planting density did not significantly affect the number of marketable heads produced per hectare. In experiment 2, 3 and 4 increasing planting density did significantly increase the number of marketable heads produced per hectare (Table 40).
- In experiment 1 and 3, the number of rows per bed did not significantly affect the number of heads picked at a planting density of 59,000 plants/ha (Table 40). In experiment 2, significantly more heads were picked from plants grown at a planting density of 59,000 plants/ha arranged in a 4 row configuration compared to a 3 row configuration at the same density.

Table 40: Number of marketable heads/ha for broccoli grown at various planting densities and row configurations on a loam soil type.

Number of rows	Planting density (plants/ha)	Between row spacing x within row spacing (cm)	Experiment 1 Nov 05 – Feb 06	Experiment 2 Jan – Apr 06	Experiment 3 Apr – Aug 06	Experiment 4 Dec 06 – Feb 07
			Viper	Viper	Ironman	Viper
2	39,216	80 x 30				35294
3	44,118	45 x 40	42484	40196	43137	40616
4	47,059	35 x 50	45752	46634	46922	
2	51,151	80 x 23				48039
4	52,288	35 x 45				51242
3	58,824	45 x 30	56209	54575	58824	52661
4	58,824	35 x 40	51961	58150	58765	
4	69,204	35 x 34				68542
Effect of number of rows: P value (lsd 5%)			ns	<0.001 (996)	0.003 (2476)	<0.001 (4212)
Effect of planting density within each row configuration: P value (lsd 5%)			ns	<0.001 (1408)	0.001 (3501)	<0.001 (5946)
P value and linear spacing contrast within 3 row configuration			ns	0.03 (-1438)	ns	ns
P value and linear spacing contrast within 4 row configuration			ns	0.03 (-752)	ns	0.03 (-1664)

Average head weight (grams)

- Increasing planting density significantly decreased the average weight of heads in all experiments (Table 41).
- The row configuration used at 59,000 plants/ha did not significantly affect the average weight of heads (Table 41).

Table 41: Average weight of heads (g) produced by plants grown at various planting densities and row configurations on a loam soil type.

Number of rows	Planting density (plants/ha)	Between row spacing x within row spacing (cm)	Experiment 1 Nov 05 – Feb 06	Experiment 2 Jan – Apr 06	Experiment 3 Apr – Aug 06	Experiment 4 Dec 06– Feb 07
			Viper	Viper	Ironman	Viper
2	39,000	80 x 30				442.82
3	44,000	45 x 40	384.19	291.3	325.99	464.11
4	47,000	35 x 50	363.15	288.4	301.62	
2	51,000	80 x 23				408.29
4	52,000	35 x 45				350.20
3	59,000	45 x 30	290.45	225.7	249.47	340.55
4	59,000	35 x 40	299.67	242.7	240.75	
4	69,000	35 x 34				283.09
Effect of number of rows: P value (lsd 5%)			ns	ns	ns	ns
Effect of planting density within each row configuration: P value (lsd 5%)			0.008 (42.1)	0.05 (56.1)	0.014 (44.6)	0.009 (71.3)
P value and linear spacing contrast within 3 row configuration			ns	ns	0.004 (7.7)	ns
P value and linear spacing contrast within 4 row configuration			ns	ns	ns	ns

Average head size (diameter (cm))

- Increasing planting density significantly decreased the average size of heads in experiment 1 and 4 but had little effect on the average size of heads in experiment 2 and 3 (Table 42).
- The alteration of row configuration at a planting density of 59,000 plants/ha had no significant effect on the average size of heads in experiment 1, 2 and 3 (Table 42).

Table 42: Average size of heads (diameter (cm)) produced by broccoli crops grown at various planting densities and row configurations on a loam soil type.

Number of rows	Planting density (plants/ha)	Between row spacing x within row spacing (cm)	Experiment 1 Nov 05 – Feb 06	Experiment 2 Jan – Apr 06	Experiment 3 Apr – Aug 06	Experiment 4 Dec 06 – Feb 07
			Viper	Viper	Ironman	Viper
2	39,000	80 x 30				14.46
3	44,000	45 x 40	13.08	11.81	12.26	14.62
4	47,000	35 x 50	12.69	11.73	12.86	
2	51,000	80 x 23				13.85
4	52,000	35 x 45				13.02
3	59,000	45 x 30	11.56	10.58	11.88	13.38
4	59,000	35 x 40	11.73	11.20	11.68	
4	69,000	35 x 34				12.28
Effect of number of rows: P value (lsd 5%)			ns	ns	ns	ns
Effect of planting density within each row configuration: P value (lsd 5%)			0.016 (0.9)	ns	ns	ns
P value and linear spacing contrast within 3 row configuration			ns	ns	ns	0.03 (0.1)
P value and linear spacing contrast within 4 row configuration			0.03 (0.1)	ns	ns	ns

Uniformity of head maturation

Number of harvests required to completely remove crop:

- Increasing planting density and alteration of the row configuration had no significant effect on the number of picks required to harvest the crop (Table 43).

Table 43: Number of harvests required for broccoli crops grown at various planting densities and row configurations on a loam soil type.

Number of rows	Planting density (plants/ha)	Between row spacing x within row spacing (cm)	Experiment 1 Nov 05 – Feb 06	Experiment 2 Jan – Apr 06	Experiment 3 Apr – Aug 06	Experiment 4 Dec 06 – Feb 07
			Viper	Viper	Ironman	Viper
2	39,000	80 x 30				1.0
3	44,000	45 x 40	1.0	1.0	2.0	1.0
4	47,000	35 x 50	1.0	1.0	2.0	
2	51,000	80 x 23				1.0
4	52,000	35 x 45				1.0
3	59,000	45 x 30	1.0	1.0	2.0	1.0
4	59,000	35 x 40	1.0	1.0	2.0	
4	69,000	35 x 34				1.0

Weight ranges:

Experiment 1, 2 and 3: The largest percentages of heads within the crop weighing between 300 g and 500 g were achieved at planting densities of 44,000 plants/ha and 47,000 plants/ha (Figure 6). At 59,000 plants/ha, the percentage of heads weighing above 500 g was minimal while the percentage of heads weighing less than 300g increased.

Experiment 4: As planting density increased, the percentage of heads weighing above 500 g decreased and the percentage of heads weighing less than 300 g increased (Figure 6). Planting densities of 51,000 plants/ha and 52, 000 plants/ha produced the greatest percentage of heads between 300 g and 500 g.

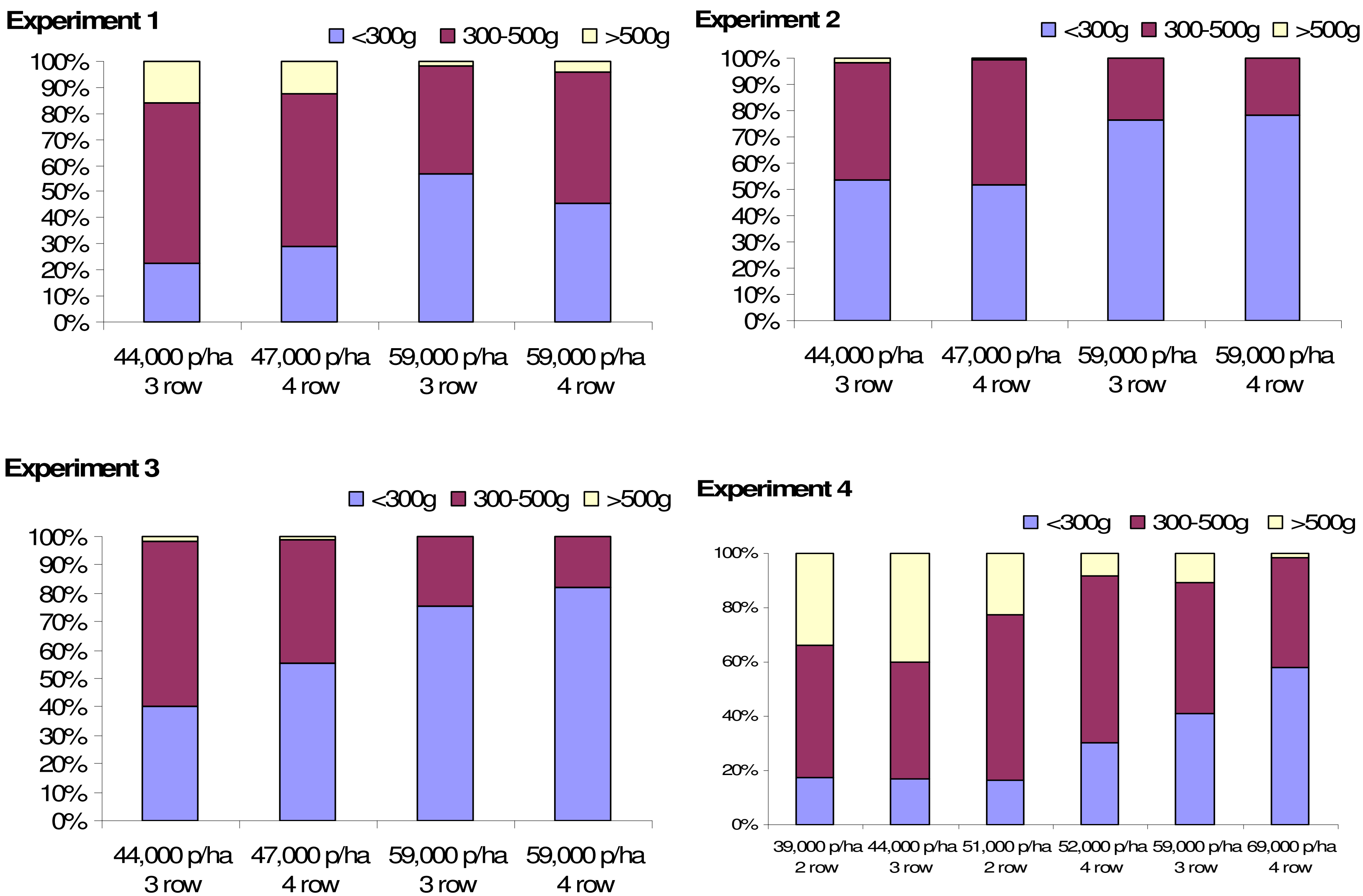


Figure 6: Percentage of crop weighing less than 300g, 300-500g and greater than 500g at each planting configuration assessed during field experiments at the loam soil site.

Broccoli – Sandy soil

Total Yield (tonnes per hectare)

- Increasing planting density significantly increased the total yield produced by crops in all field experiments (Table 44).
- Increasing the number of rows per bed from 2 to 4 at 39,000 plants/ha, 47,000 plants/ha and 59,000 plants/ha generally resulted in a significant decrease in the total yield produced (Table 44). In experiment 3, increasing the number of rows per bed from 2 to 4 at a planting density of 39,000 plants/ha significantly increased the total yield produced.
- There was a significant difference in the total yield produced by varieties in experiment 2, 3 and 4 (Table 44). 'Ironman' consistently produced higher total yields than 'Endurance' at all planting densities and row configurations. An exception to this was plants grown at 29,000 plants/ha in a 2 row configuration during experiment 4 where both 'Ironman' and 'Endurance' produced the same total yield.

Table 44: Total yield (t/ha) produced by broccoli crops grown at various planting densities and row configurations on a sandy soil type.

Number of rows	Planting density (plants/ha)	Between row spacing x within row spacing (cm)	Experiment 1 Jan - Apr 06	Experiment 2 May - Jul 06		Experiment 3 Aug -Nov 06		Experiment 4 Mar – May 07	
			Ironman	Ironman	Endurance	Ironman	Endurance	Ironman	Legacy
2	29,000	80 x 40		11.29	10.12	18.44	15.49	14.62	14.29
3	35,000	45 x 50	10.50	12.67	10.25	20.69	18.17	16.93	14.55
2	39,000	80 x 30		13.22	11.65	21.62	17.79		
4	39,000	35 x 60	9.90	11.74	11.11	22.90	18.56	17.78	15.51
3	44,000	45 x 40	11.60	16.80	11.54	22.58	19.43	18.54	16.39
2	47,000	80 x 25				23.44	20.30	19.05	16.56
4	47,000	35 x 50	12.10	14.38	13.09	22.07	19.89		
3	59,000	45 x 30		17.76	15.22	26.35	20.09	21.16	18.38
4	59,000	35 x 40		14.43	13.43				
Number of rows effect: P value (lsd 5%)			ns	<0.001 (0.8)		0.01 (1.2)		<0.001 (0.6)	
Effect of planting density within each row configuration: P value (spacing contrast)			0.03 (-0.2)	<0.001 (1.2)		<0.001 (1.8)		<0.001 (0.8)	
Varietal effect: P value (lsd 5%)			ns	<0.001 (0.6)		<0.001 (0.9)		<0.001 (0.4)	
Interaction between variety, number of rows and spacing: P value (lsd 5%)			ns	ns		ns		ns	
Interaction between variety and number of rows: P value (lsd 5%)			ns	0.006 (1.1)		ns		ns	

Marketable Yield – export market specifications (tonnes per hectare)

- Within a 2 row configuration marketable yield was observed to increase significantly with increasing planting density in experiment 2, 3 and 4 (Table 45). In experiment 2 and 4, plants grown in a 3 row configuration produced significantly more marketable yield when planting density increased. In experiment 1 increasing planting density in a 3 row configuration significantly decreased marketable yield and in experiment 3 increasing planting density in a 3 row configuration had no effect on the marketable yield produced. Increasing planting density in a 4 row configuration did not significantly affect marketable yield except in experiment 2 where 'Endurance' was observed to produce significantly more marketable yield as planting density increased.

- At 39,000 plants/ha and 59,000 plants/ha, the marketable yield produced decreased significantly when the number of rows was increased in experiment 2 (Table 45). In experiment 1 and 3, there was no significant difference in yield achieved between plants grown in a 2, 3 or 4 row configuration at planting densities of 39,000 plants/ha and 47,000 plants/ha.
- ‘Ironman’ produced significantly higher marketable yields than ‘Endurance’ and ‘Legacy’ at all planting densities during all field experiments (Table 45).

Table 45: Marketable yield (t/ha) produced by broccoli crops grown at various planting densities and row configurations on a sandy soil type.

Number of rows	Planting density (plants/ha)	Between row spacing x within row spacing (cm)	Experiment 1 Jan - Apr 06	Experiment 2 May – Jul 06		Experiment 3 Aug – Nov 06		Experiment 4 Mar – May 07	
			Ironman	Ironman	Endurance	Ironman	Endurance	Ironman	Legacy
2	29,000	80 x 40		11.11	9.54	18.13	14.90	14.38	13.33
3	35,000	45 x 50	10.20	12.46	9.87	20.57	16.44	16.12	13.56
2	39,000	80 x 30	11.30	16.73	11.38	22.05	17.25	17.95	15.36
4	39,000	35 x 60		13.02	11.26	20.84	16.64		
3	44,000	45 x 40	9.70	11.54	10.58	20.97	16.44	17.06	14.53
2	47,000	80 x 25				22.28	17.38	18.08	15.18
4	47,000	35 x 50	11.80	13.94	12.55	21.64	18.01		
3	59,000	45 x 30		17.64	14.61	22.38	15.31	20.92	16.15
4	59,000	35 x 40		14.18	12.70				
Number of rows effect: P value (lsd 5%)			ns	<0.001 (0.8)		ns		0.001 (0.9)	
Effect of planting density within each row configuration: P value (spacing contrast)			0.02 (-0.2)	<0.005 (1.2)		0.03 (2.0)		<0.001 (1.1)	
Varietal effect: P value (lsd 5%)			ns	<0.001 (0.6)		<0.001 (1.0)		<0.001 (0.6)	
Interaction between variety, number of rows and spacing: P value (lsd 5%)			ns	ns		ns		ns	
Interaction between variety and number of rows: P value (lsd 5%)			ns	0.006 (1.1)		ns			

Number of marketable heads produced per hectare – domestic market specifications

- Increasing planting density significantly increased the number of marketable heads produced per hectare in all experiments (Table 46).
- Plants grown at 47,000 plants/ha and 59,000 plants/ha were not significantly affected when the row configuration was altered (Table 46). At a planting density of 39,000 plants/ha 'Endurance' in experiment 3 produced an extra 2286 heads per hectare when grown in a 2 row configuration compared to a 4 row configuration.
- In experiment 2, 'Endurance' and 'Ironman' generally produced the same number of marketable heads at most planting densities (Table 46). However when grown at a planting density of 47,000 plants/ha in a 4 row configuration and at a planting density of 59,000 plants/ha in a 3 row configuration 'Ironman' produced significantly more marketable heads than 'Endurance'. In experiment 3, 'Ironman' generally produced significantly more marketable heads per hectare than 'Endurance', except at a planting density of 29,000 plants/ha in a 2 row configuration, where both varieties produced the same number of marketable heads. In experiment 4, 'Ironman' generally produced more marketable heads per hectare than 'Legacy' except at a planting density of 35,000 plants/ha and 39,000 plants/ha where both varieties produced the same number of marketable heads.

Table 46: Number of marketable heads produced per hectare by broccoli crops grown at various planting densities and row configurations on a sandy soil type.

Number of rows	Planting density (plants/ha)	Between row spacing x within row spacing (cm)	Experiment 1 Jan - Apr 06	Experiment 2 May – Jul 06		Experiment 3 Aug – Nov 06		Experiment 4 Mar – May 07	
			Ironman	Ironman	Endurance	Ironman	Endurance	Ironman	Legacy
2	29,412	80 x 40		27984	28230	28710	28044	28824	26471
3	35,294	45 x 50	33775	33544	34585	34948	31957	33382	32500
2	39,216	80 x 30		37313	38839	38252	35946		
4	39,216	35 x 60	38143	38380	36975	38267	33660	37255	36209
3	44,118	45 x 40	42227	41334	42209	42734	38201	42059	40294
2	47,059	80 x 25				43924	39503	44118	41618
4	47,059	35 x 50	45587	46329	44898	45852	41283		
3	58,824	45 x 30		57890	55300	49624	42294	56471	46029
4	58,824	35 x 40		57143	56957				
Number of rows effect: P value (lsd 5%)			ns	<0.001 (2280.1)		<0.001 (2179.7)		ns	
Effect of planting density within each row configuration: P value (spacing contrast)			0.002 (-763)	<0.001 (3532.4)		<0.001 (3376.8)		<0.001 (2444.4)	
Varietal effect: P value (lsd 5%)			ns	0.03 (1766.2)		<0.001 (1688.4)		<0.001 (1411.3)	
Interaction between variety, number of rows and spacing: P value (lsd 5%)			ns	<0.001 (4995.5)		ns		0.001 (3457.0)	
Interaction between variety and number of rows: P value (lsd 5%)			ns	<0.001 (3224.6)		ns		ns	

Average head weight (grams)

- Increasing planting density significantly decreased the average weight of heads in experiment 2, 3 and 4 (Table 47). In experiment 1 the average weight of heads was not significantly affected by increasing planting density.
- Increasing the number of rows from 2 to 4 at a planting density of 39,000 plants/ha did not have a significant effect on the weight of 'Ironman' and 'Endurance' heads in experiment 2. For experiment 3, the increase in row number resulted in a significant increase in the average head weight (Table 47). At 47,000 plants/ha and 59,000 plants/ha increasing the number of rows to 4 significantly decreased the weight of 'Ironman' heads but had no significant effect on the weight of 'Endurance' heads.
- 'Ironman' generally produced significantly heavier heads than 'Endurance' and 'Legacy' (Table 47). Exceptions to this occurred during experiment 2 where plants from both varieties grown at 39,000 plants/ha in a 4 row configuration produced the same head weight and during experiment 4 where plants from both varieties grown at 29,000 plants/ha in a 2 row configuration produced the same head weight.

Table 47: Average weight of heads (g) produced by broccoli crops grown at various planting densities and row configurations on a sandy soil type.

Number of rows	Planting density (plants/ha)	Between row spacing x within row spacing (cm)	Experiment 1 Jan - Apr 06	Experiment 2 May – Jul 06		Experiment 3 Aug – Nov 06		Experiment 4 Mar – May 07	
			Ironman	Ironman	Endurance	Ironman	Endurance	Ironman	Legacy
2	29,000	80 x 40		351.28	312.81	596.38	489.84	497.23	488.32
3	35,000	45 x 50	262.20	333.35	267.39	557.26	472.17	479.69	412.21
2	39,000	80 x 30		318.84	282.90	520.19	443.66		
4	39,000	35 x 60	244.80	303.78	295.21	555.11	473.39	454.83	395.50
3	44,000	45 x 40	254.50	337.93	249.46	483.30	415.74	420.31	377.67
2	47,000	80 x 25				475.55	420.53	406.10	356.38
4	47,000	35 x 50	248.70	291.43	277.10	444.72	416.40		
3	59,000	45 x 30		289.71	250.79	431.62	335.84	358.02	328.58
4	59,000	35 x 40		261.31	249.51				
Number of rows effect: P value (lsd 5%)			ns	<0.001 (13.9)		0.01 (28)		ns	
Effect of planting density within each row configuration: P value (spacing contrast)			ns	<0.001 (21.5)		<0.001 (43.4)		<0.001 (17.6)	
Varietal effect: P value (lsd 5%)			ns	<0.001 (10.8)		<0.001 (21.7)		<0.001 (10.2)	
Interaction between variety, number of rows and spacing: P value (lsd 5%)			ns	ns		ns		0.02 (24.9)	
Interaction between variety and number of rows: P value (lsd 5%)			ns	0.002 (19.7)		ns		ns	

Average head size (diameter (cm))

- Increasing planting density did not have a significant effect on the average size of heads for plants grown in experiment 1, 2 and 3 (Table 48). In experiment 4, increasing planting density significantly decreased the average size of heads.

- Alteration of the row configuration at 39,000 plants/ ha, 47,000 plants/ha and 59,000 plants/ha had no significant effect on the average size of heads from all field experiments (Table 48).
- ‘Ironman’, ‘Endurance’ and ‘Legacy’ all produced heads of the same size at all planting configurations assessed (Table 48).

Table 48: Average diameter of heads (cm) produced by broccoli crops grown at various planting densities and row configurations on a sandy soil type.

Number of rows	Planting density (plants/ha)	Between row spacing x within row spacing (cm)	Experiment 1 Jan - Apr 06	Experiment 2 May – Jul 06		Experiment 3 Aug – Nov 06		Experiment 4 Mar – May 07	
			Ironman	Ironman	Endurance	Ironman	Endurance	Ironman	Legacy
2	29,000	80 x 40		12.42	12.33	15.38	14.52	15.03	15.41
3	35,000	45 x 50	12.20	12.20	12.58	15.31	14.65	14.36	14.16
2	39,000	80 x 30		12.31	12.15	15.08	14.19		
4	39,000	35 x 60	11.90	12.70	12.28	14.79	14.78	14.15	14.33
3	44,000	45 x 40	12.10	12.88	11.65	14.71	13.97	13.84	13.96
2	47,000	80 x 25				14.62	15.20	13.93	13.82
4	47,000	35 x 50	12.00	12.02	11.89	14.33	14.11		
3	59,000	45 x 30		12.01	11.72	14.82	12.88	13.32	13.59
4	59,000	35 x 40		11.72	11.55				
Number of rows effect: P value (lsd 5%)			ns	ns		ns		ns	
Effect of planting density within each row configuration: P value (spacing contrast)			ns	ns		ns		<0.001 (0.48)	
Varietal effect: P value (lsd 5%)			ns	ns		ns		ns	
Interaction between variety, number of rows and spacing: P value (lsd 5%)			ns	ns		ns		ns	
Interaction between variety and number of rows: P value (lsd 5%)			ns	ns		ns		ns	

Uniformity of head maturation: Number of harvests required to remove crop

- Increasing planting density had no significant effect on the number of harvests required to remove crops during all field experiments (Table 49).
- Alteration of the row configuration at 39,000 plants/ha, 47,000 plants/ha and 59,000 plants/ha had no significant effect on the number of harvests required (Table 49).
- There was no varietal effect on the number of harvests required for experiment 1, 2 and 3 (Table 49). In experiment 4, 'Ironman' required significantly less picks than 'Legacy' when grown at 29,000 plants/ha, 35,000 plants/ha, 47,000 plants/ha and 59,000 plants/ha.

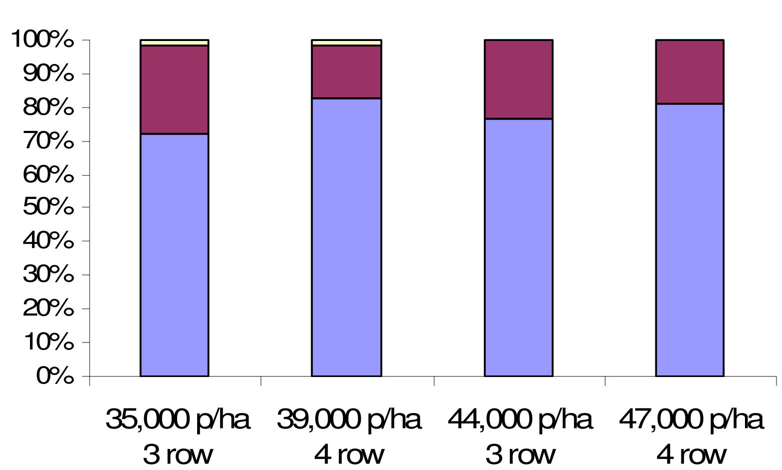
Table 49: Number of harvests required to remove broccoli crops grown at various planting densities and row configurations on a sandy soil type.

Number of rows	Planting density (plants/ha)	Between row spacing x within row spacing (cm)	Experiment 1 Jan - Apr 06	Experiment 2 May – Jul 06		Experiment 3 Aug – Nov 06		Experiment 4 Mar – May 07	
				Ironman	Endurance	Ironman	Endurance	Ironman	Legacy
2	29,000	80 x 40		4.00	4.00	2.00	1.50	2.40	2.80
3	35,000	45 x 50	2.00	4.00	4.00	2.00	3.00	2.60	3.00
2	39,000	80 x 30		4.00	4.00	2.50	2.50		
4	39,000	35 x 60	2.00	4.00	4.50	2.50	2.50	3.00	3.00
3	44,000	45 x 40	2.00	4.00	4.00	2.50	3.00	3.00	3.00
2	47,000	80 x 25				2.50	3.00	2.60	3.00
4	47,000	35 x 50	2.00	4.00	3.50	3.00	2.50		
3	59,000	45 x 30		4.50	4.50	3.00	3.00	2.60	3.00
4	59,000	35 x 40		2.50	5.00				
Number of rows effect: P value (lsd 5%)			ns	ns		ns		ns	
Effect of planting density within each row configuration: P value (spacing contrast)			ns	ns		ns		ns	
Varietal effect: P value (lsd 5%)			ns	ns		ns		0.003 (0.2)	

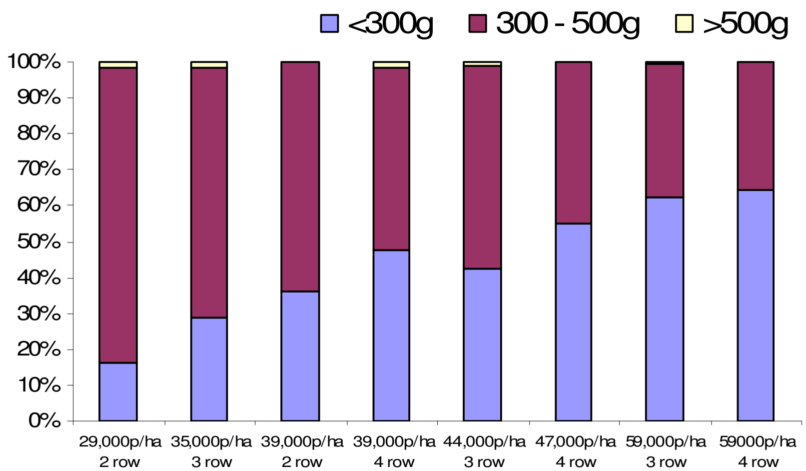
Weight ranges:

Heads harvested from experiment 1 and 2 were cut for export market specifications and therefore the percentage of heads weighing less than 300g in these experiments is generally much higher than experiment 3 and 4, which were cut to domestic market specifications. Generally as planting density increased the percentage of heads weighing above 500g decreased and the percentage of heads which weighed less than 300g increased. 'Ironman' was observed to be more sensitive to changes in planting density than 'Endurance'. The percentage of 'Ironman' heads which weighed less than 300g was observed to increase substantially with increasing planting density however in 'Endurance' crops the effect was not as strong.

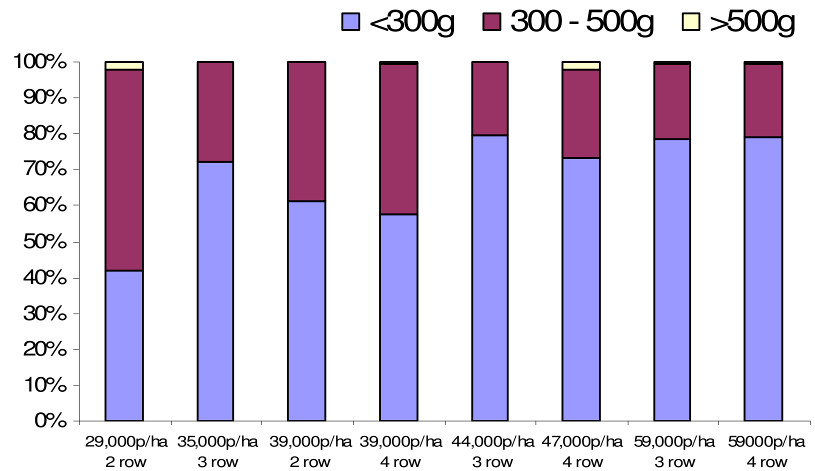
Experiment 1



Experiment 2 - Ironman



Experiment 2 - Endurance



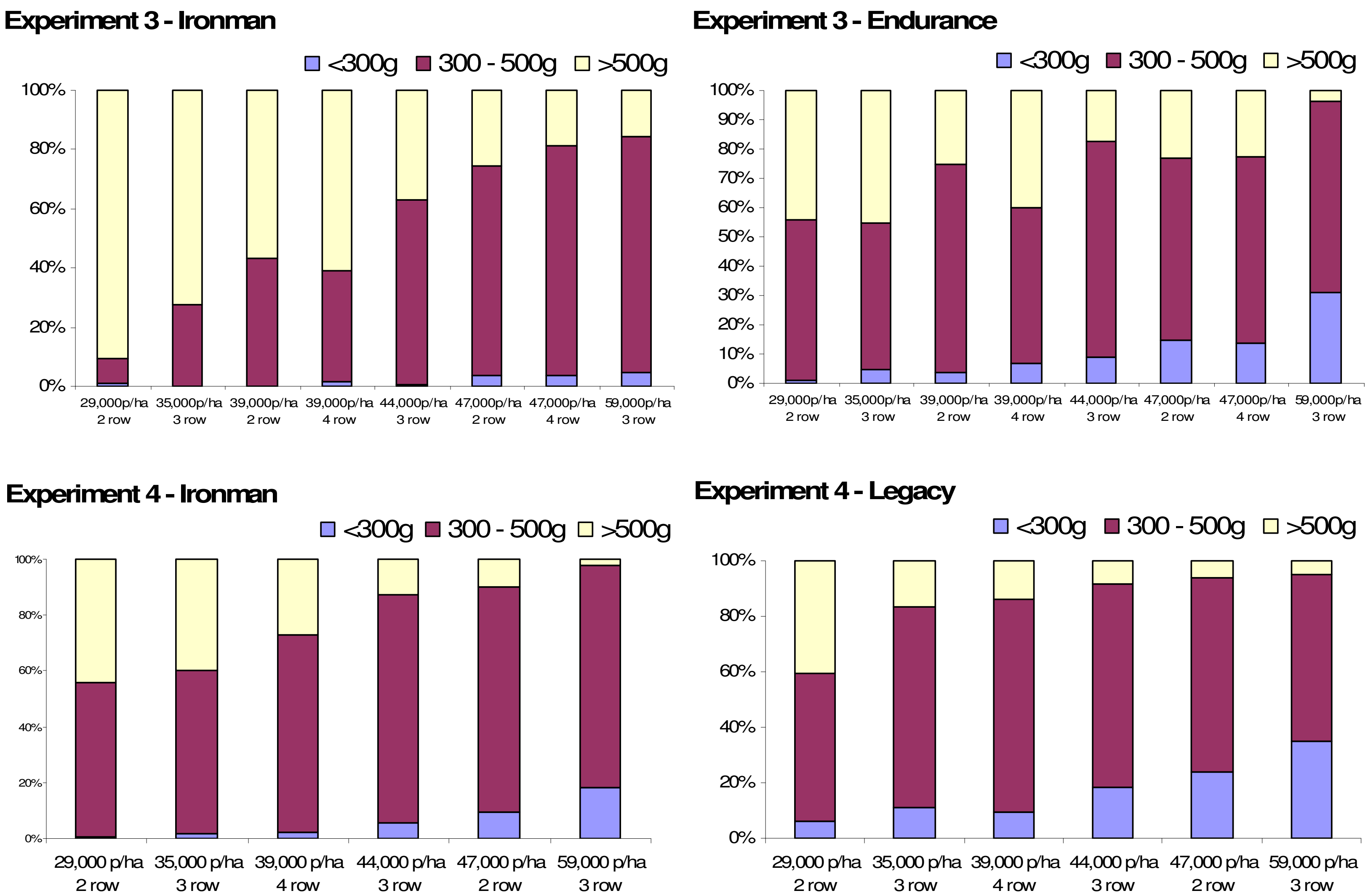


Figure 7: Percentage of crop weighing less than 300g, 300 – 500g and greater than 500g at all planting configurations assessed during field experiments at the sandy soil site.

A summary of all the results from the planting configuration experiments is available on pages 96 to 100.

Assessment of alternative covering mechanisms for high density crops

Introduction

Cauliflower curds exposed to sunlight as they mature develop a yellow discoloration which depending on the severity may render them unmarketable. To prevent yellowing, curds are covered manually by folding or breaking the surrounding leaves of the plant over the developing curd prior to harvest. Covering of crops by hand was made difficult due to the close proximity of plants grown in three and four row configurations. It was deemed necessary to develop an alternative method of covering high density crops which would not require repeated movement through the crop.

To investigate alternative methods for covering of cauliflower crops a range of shade cloth was placed over sections of a mature cauliflower crop approximately four weeks prior to harvest commencing. The shade cloth assessed consisted of a range of colours (red, black, green and white) and block-out (30%, 50% and 70% light transmission). Harvest characteristics of curds produced by plants underneath the shade cloth were assessed and compared to sections of the crop which were either not covered and harvested once, or manually covered by hand with either a single (one pass harvest (OPH)) or selective (multiple) harvests (SH).

Figure 8: Cauliflower crop covered with range of shade cloth prior to harvest.

All curds were weighed so that the average weight could be calculated and the total yield (all curds harvested) and marketable yield (harvested curds which met product specifications) calculated. Curds were graded according to the degree of yellowing with the whitest curds assigned a grade of 1 through to 5 for the highest degree of yellowing. The primary reason why curds did not meet market specifications was recorded. Curds were rendered unmarketable because they were too yellow, too small (below 500 grams) or over mature. The ability of water to transfer through the cloth was measured using a rain gauge and the level of light under each type of shade cloth available to plants for photosynthetic use (PAR) measured using a light meter. Management issues associated with covering crops with shade cloth were also investigated.

Figure 9: Scale of yellowing used to grade curds. Whitest curds were assigned a grade of one (far left) through to five for the highest degree of yellowing (far right).

Results and discussion:

White shade cloth with a light transmission of 50% was the most successful at reducing curd yellowing whilst maintaining marketable yield. Plants covered with this cloth produced the highest yield of marketable curds (Figure 7), maintained an acceptable curd weight of approximately 900g (Figure 8) and had the whitest marketable curds (Figure 9). The performance of plants under this cloth was similar to plants which were manually covered and harvested once (OPH) although a minor reduction in the average curd weight and total yield was observed.

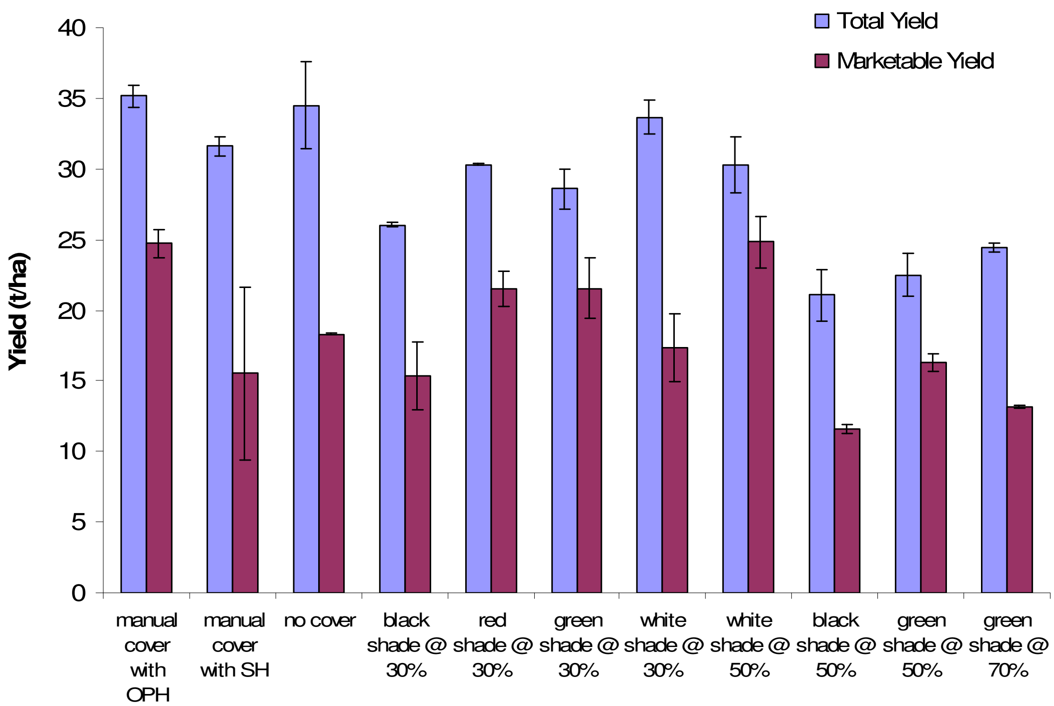


Figure 10: Total and marketable yield (t/ha) of cauliflower curds harvested from plants under shade cloth, manually covered or uncovered. Bars represent S.E (*n* = 2).

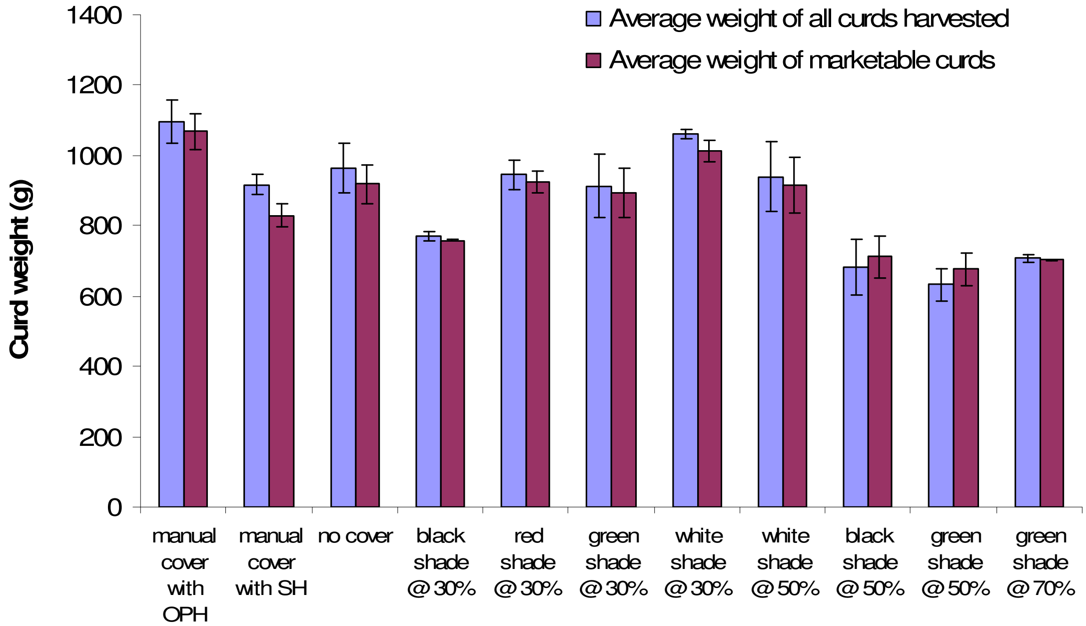


Figure 11: Average weight (g) of all cauliflower curds harvested and curds suitable for sale from plants grown under shade cloth, manually covered or uncovered. Bars represent S.E (*n* = 2).

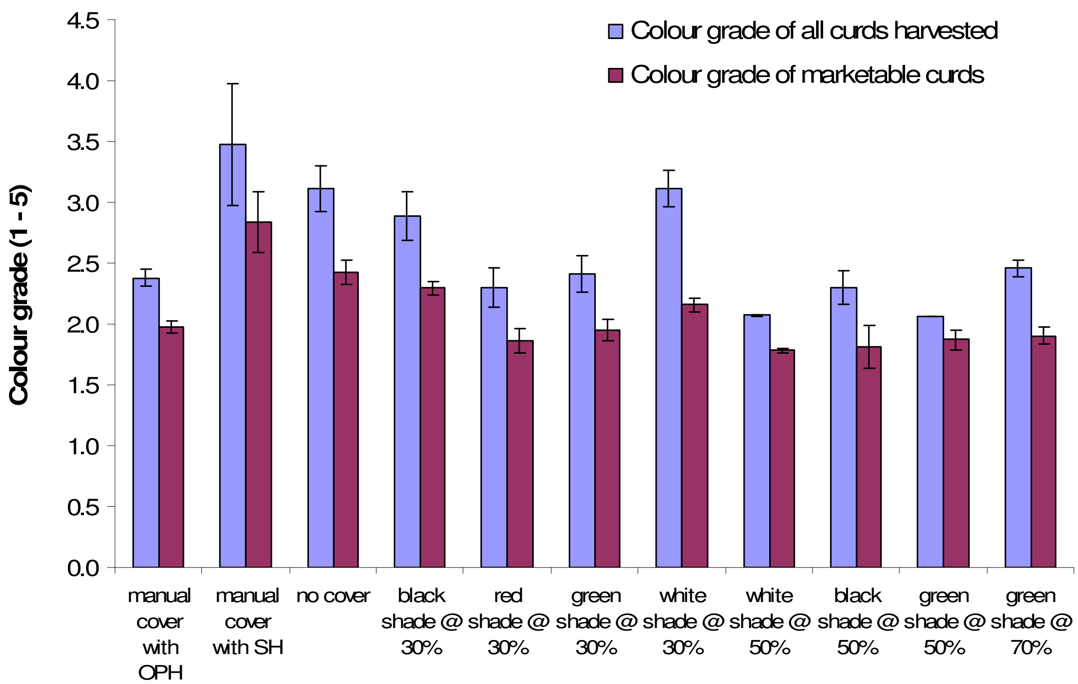


Figure 12: Colour score of total and market grade cauliflower curds. One indicates curds most white in colour and five indicates curds with the most severe yellowing. Bars represent S.E (*n* = 2).

Plants covered by shade cloth with a light suppression of 50% or higher generally had whiter curds than those covered manually or with less than 50% light suppression however yield was reduced due to a lower average curd weight. The exception to this was the white shade cloth where yield was not reduced and curd weight was maintained. The reduction in curd weight could be attributed to reduced photosynthetic activity as a result of lower light levels. A higher percentage of over mature curds were harvested from plants under shade cloth with block out of 50% or greater (Figure 10). Previous research (Tarakanov, 2006) has shown that low light levels can modify plant development and in this case reduced light transmission may be acting as a stress trigger inducing earlier maturation.

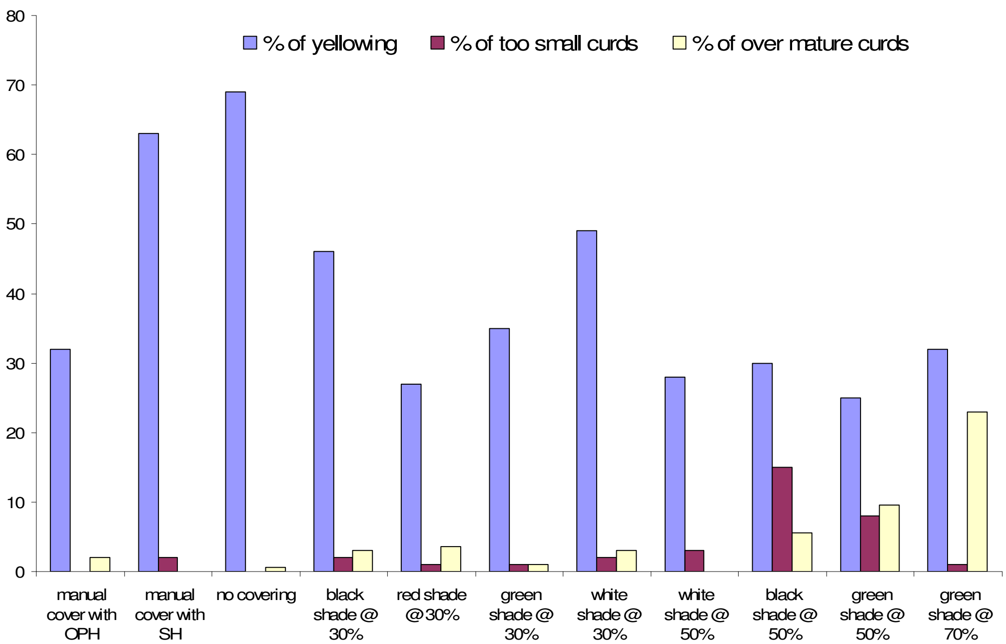


Figure 13: Primary reason for unmarketable curds harvested from plants under shade cloth, manually covered or uncovered.

Red and green shade cloth with a light suppression of 30% produced marketable yields with lower amounts of curd yellowing compared to black and white cloths with the same light transmission. However all of these cloths resulted in plants producing lower marketable yields with higher percentages of yellowing compared to plants under the 50% white shade cloth or those manually covered once.

Plants which were manually covered and harvested only once (OPH) produced higher yields and curds of a whiter colour than plants which were manually covered and selectively harvested. One replicate of the selectively harvested plants produced a very low marketable yield due to the majority of curds being over mature and very yellow. Plants within this replicate should have been harvested at an earlier stage which would have prevented the loss in marketable yield and yellowing. Due to the low number of replicates this data was not removed from analysis. However under ideal conditions it would be expected that curds produced by plants which had been manually covered and selectively harvested would be of similar quality to that produced by plants which were harvested only once.

Plant frames did not appear to be physically damaged by the weight of the cloths tested. Rain gauges were placed under cloth with 30%, 50% and 70% light transmission. Transmittance of water through these cloths was not significantly affected indicating that irrigation of summer crops under shade cloth should not be an issue. It was not possible to assess whether pest control would be more difficult as it was not necessary to spray for Diamondback Moth *(Plutella xylostera)* during the time plants were covered. As the shade cloth is on the crop for a short period of time and if adequate pest control is applied prior to application, the cloth is not likely to seriously impede pest and disease management.

Conclusion:
Placement of white shade cloth with a light transmission of 50% is a viable alternative to manually covering cauliflower curds. Curds harvested from plants underneath this type of cloth were of similar weight and quality to those harvested from plants which were manually covered.

Economic Analysis of Alternative Planting Configurations:

Economic analysis of the costs and benefits associated with alternative planting configurations was conducted for cauliflower crops harvested for both domestic and export market specifications. The enterprise margin has been calculated by determining the gross margin minus 'other costs' (overhead costs such as machinery replacement, land rates, insurance etc) and is therefore a better reflection of the profitability of the whole business and not just one crop.

A number of assumptions were made when calculating the costs associated with production. These included:

1. The market price is unaffected by a per unit increase in production i.e. that with increases in the amount of product supplied to the market the unit price received by growers does not decrease.
2. 'Other costs' included in analysis consists of over-head costs such as the cost of replacing machinery, land rates, insurance, interest paid on loans etc. These overhead costs are spread over a cultivated area of 72 hectares which consists of 12 hectares of cauliflower grown in conjunction with 60 hectares of another horticultural crop.
3. An assumed flat-rate irrigation cost of 12 cents per hectare. In reality, irrigation costs are likely to vary according to the type of energy used to pump water (such as diesel or electric) and the source of the water (i.e. is it being pumped from a dam, shallow bore or deep bore).

Low density crops refer to those grown at 29,000 plants/ha while high density crops are those planted at 39,000 plants/ha. Two factors were also used to calculate costs associated with fertiliser and harvesting at increased planting densities. These included:

1. An assumption that plants grown at increased planting densities are more efficient at accessing available fertiliser. Therefore for every extra plant grown above 29,000 plants/ha only 50% extra fertiliser is required. Consequently when planting density is increased from 29,000 plants/ha to 39,000 plants/ha

(an increase in the number of plants of 26%), only 13% extra fertiliser has been applied to crops.

2. With increased planting density harvesting efficiency is increased by 15%. For example, within low density crops (29,000 plants/ha) approximately 141 kg of cauliflower can be harvested per hour however at increased planting densities (39,000 plants/ha) that amount is increased to approximately 161 kg per hour.

Income generated by export crops was calculated using the exportable marketable yield averaged over all field experiments multiplied by $0.80 per kilogram. Income generated by domestic crops was calculated using the number of marketable curds harvested per hectare (averaged over all field experiments) multiplied by $0.93 per curd for crops grown on sandy soils and $1.17 per head for crops grown on loam soils. This income does not account for seasonal fluctuations in production or price.

Cauliflower crops produced for export at the loam soil site achieved an increase in enterprise margin of $2,142 per hectare when grown in a four row configuration at 39,000 plants/ha and $1,184 per hectare when configured in three rows at 39,000 plants/ha (Figure 14). Increasing the number of rows per bed at a planting density of 29,000 plants/ha resulted in an enterprise margin increase of $946 per hectare.

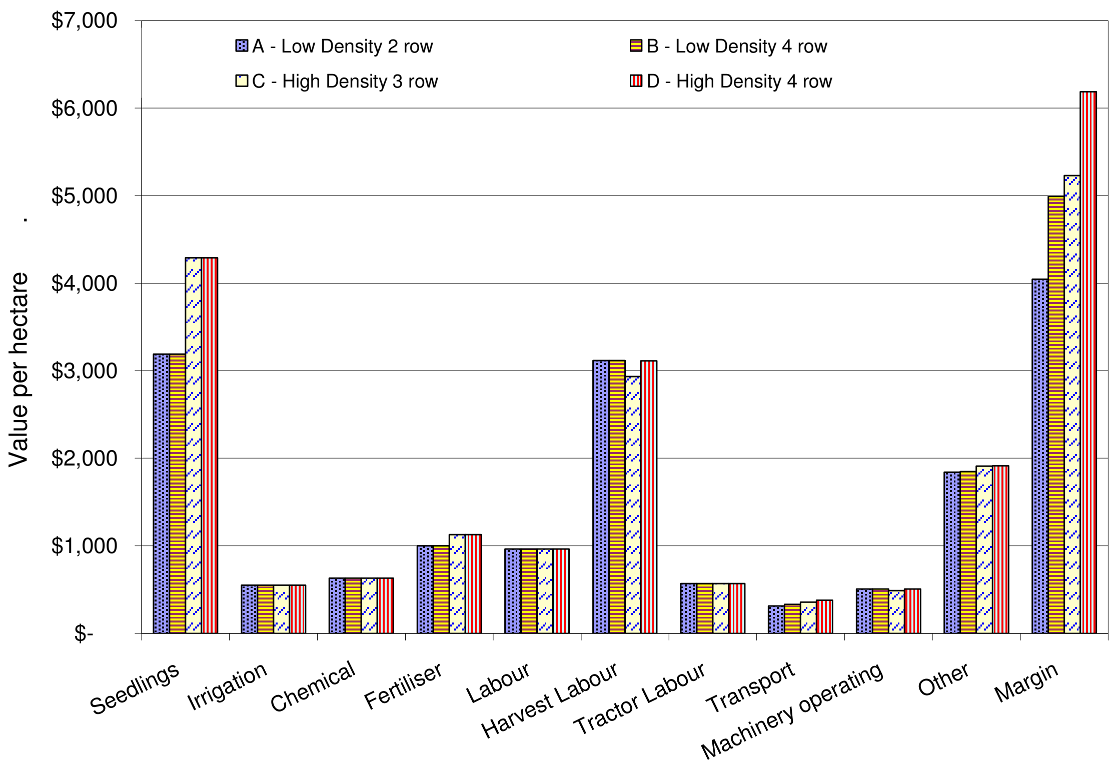


Figure 14: Average annual per hectare cost of production and enterprise margin (based on exportable marketable yield) for cauliflower crops grown on a loam soil type.

An increase in the enterprise margin of $1150 per hectare for export cauliflower crops grown on a sandy soil type occurred when planting density was increased from 29,000 plants/ha in a two row configuration to 39,000 plants/ha in a three row configuration (Figure 15). High density crops (39,000 plants/ha) configured in four rows made $32 per hectare less than low density crops (29,000 plants/ha) in a two row configuration due to the increased cost of seedlings not being off-set by an increase in marketable yield. An increase in marketable yield resulted in an enterprise margin increase of $580 per hectare when the number of rows was increased from 2 to 4 at 29,000 plants/ha.

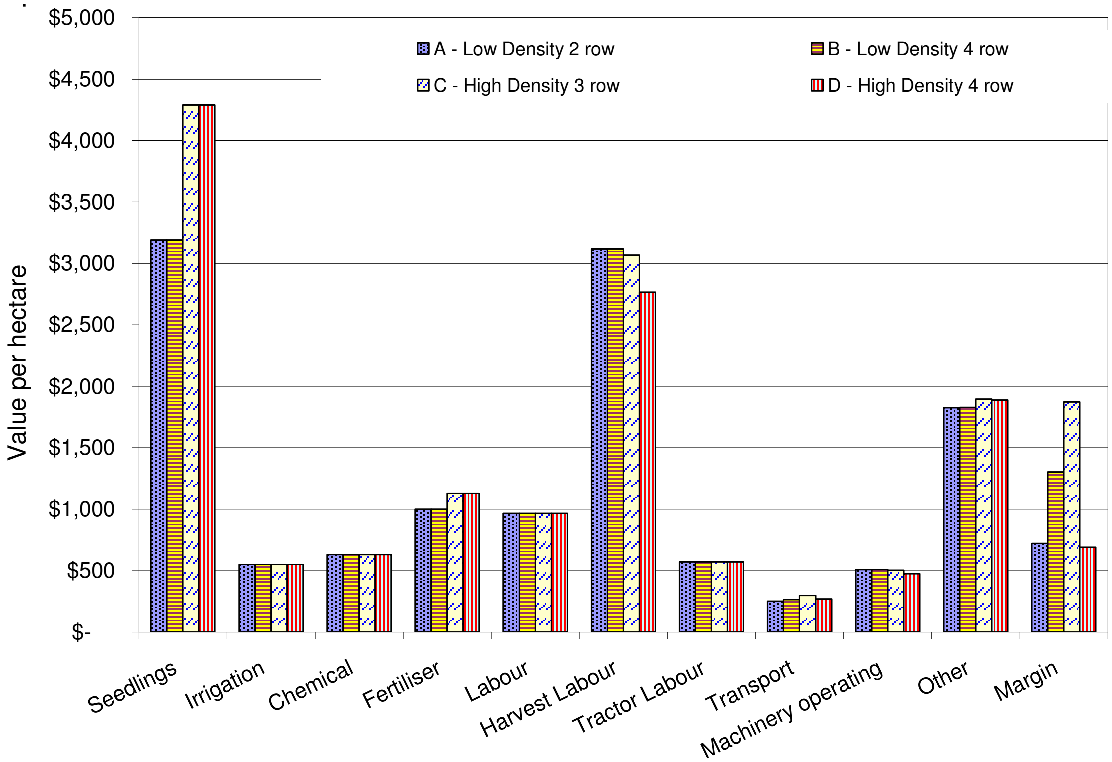


Figure 15: Average annual per hectare cost of production and enterprise margin (based on exportable marketable yield) for cauliflower crops grown on a sandy soil type.

The enterprise margin increased by $7,624 per hectare for domestic cauliflower crops grown in a four row configuration on a loam soil type when planting density was 39,000 plants/ha and by $5558 per hectare when grown in a three row configuration (Figure 16). Alteration of row configuration from two to four rows per bed at 29,000 plants/ha increased the enterprise margin by $1656 per hectare.

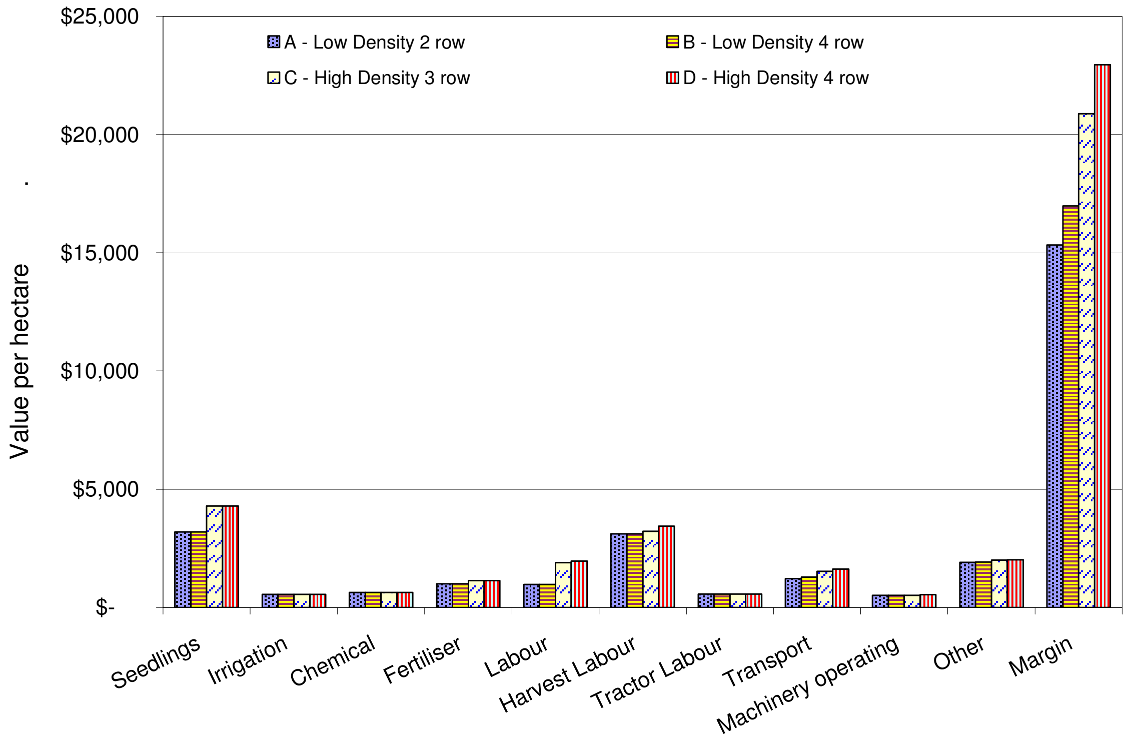


Figure 16: Average annual per hectare cost of production and enterprise margin (based on number of marketable heads per hectare) for cauliflower crops grown on a loam soil type.

The enterprise margin increased by $4592 per hectare for domestic cauliflower crops grown in a four row configuration on a sandy soil type when planting density was 39,000 plants/ha and by $4510 per hectare when grown in a three row configuration (Figure 17). Alteration of row configuration from two to four rows per bed at 29,000 plants/ha increased the enterprise margin by $271 per hectare.

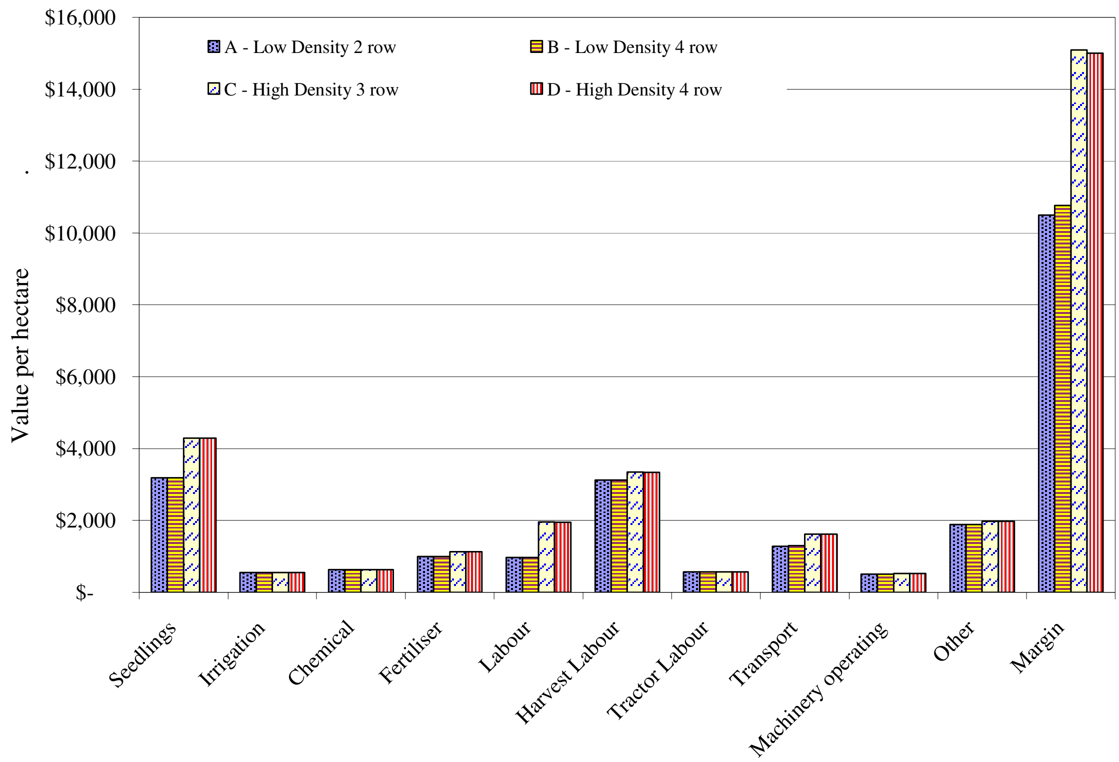


Figure 17: Average annual per hectare cost of production and enterprise margin (based on number of marketable heads per hectare) for cauliflower crops grown on a sandy soil type.

The most profitable configuration for high density crops grown on loam soils was four rows per bed while on sandy soils high density crops provided the highest economic returns when configured in three rows. Alteration of the row configuration from two to four rows at a planting density of 29,000 plants/ha consistently increased earnings on both the loam and sandy soil site. On the loam soil this effect was most noticeable when crops were produced for the domestic market however on sandy soils alteration of the row configuration resulted in a greater increase in profit for export crops.

Cauliflower planted at increased densities yielded the highest economic return when produced for the domestic market. This is due to the more relaxed product specifications required for product sold on the domestic market. Production of cauliflower for export is less profitable due to the high quality standards required and the greater amount of waste product. At increased planting densities production of high quality curds which meet ideal weight specifications is likely to be more difficult and this is reflected in the lower profit margins achieved for crops grown for export. On sandy soils, export crops grown in a four row configuration resulted in a lower profit compared to low density crops due to the difficulty in achieving set weight specifications for curds.

Results Summary

Cauliflower - Loam soil

Plant density: Increasing plant density increased the total yield and the number of marketable heads suitable for domestic market specifications in the majority of field experiments. This was reflected by an increase in economic return of $5558/ha for three row crops and $7624/ha for four row crops. The yield of curds suitable for export market specifications was not as strongly influenced by increasing plant density with a significant increase in export marketable yield occurring in only 4 out of 8 field experiments. Economic returns for export crops were still increased at higher plant densities with an increase in profit of $2,142/ha achieved by four row crops and $1,184/ha achieved by three row configurations. Increases in plant density up to 39,000 plants/ha did not appear to substantially affect curd size however increases beyond 39,000 plants/ha resulted in a significant reduction in the average curd size of approximately 12%. Increases in plant density significantly decreased the average weight of curds in the majority of experiments by approximately 19%. Uniformity of curd weight (i.e. the number of curds within the crop which weighed approximately 1.0 kg) was not significantly improved with increasing plant density. The uniformity of crop maturation was also unaffected with the number of harvests required to remove the crop not reduced by increasing plant density. Although manual covering of crops was made more difficult at increased plant densities, particularly the highest densities, the level of curd yellowing was generally not increased within high density crops.

Planting configuration: Generally alteration of the row configuration at 29,000 plants/ha and 39,000 plants/ha did not have a significant effect on the majority of harvest characteristics assessed. Minor increases in yield and number of marketable curds per hectare were observed when the row number was increased from two to either three or four rows per bed and this was reflected in an increased enterprise margin return of $946/ha for export crops and $1656/ha for domestic market crops. Planting configuration was observed to have an effect on crop maturation uniformity in a number of field experiments. Plants grown at 29,000 plants/ha in a 2 row configuration appeared to mature earlier and more uniformly than plants grown in 4 row configurations. Plants grown at 39,000 plants/ha appeared to mature more uniformly when grown in a three row configuration compared to a four row configuration. ‘Aviron’ matured earlier than ‘Summer Love’ during the autumn production period and ‘Granite’ matured earlier than ‘Starlight’ during winter.

Varietal performance: On loam soils significant differences in varietal performance were observed during all seasonal periods. ‘Monarch’ produced higher total and marketable yields at all planting densities and row configurations compared to ‘Moby’. ‘Monarch’ produced heavier curds at a planting density of 29,000 plants/ha but at 39,000 plants/ha both ‘Monarch’ and ‘Moby’ produced the same average curd weight. At both planting densities ‘Monarch’ and ‘Moby’ produced the same sized curds and required the same number of harvests. ‘Monarch’ had more severe curd yellowing than ‘Moby’ but had a lower percentage of ‘too small’ curds at all planting densities and row configurations.

‘Aviron’ produced larger and heavier curds than ‘Summer Love’ resulting in a significantly higher total yield. However a substantial percentage of these curds were of poor quality resulting in 'Summer Love' crops producing higher yields of marketable curds than 'Aviron'. At 29,000 plants/ha 'Aviron' produced heavier curds than 'Summer Love' but at 39,000 plants/ha they produced the same curd weight. 'Aviron' matured more uniformly than 'Summer Love' requiring less harvests to remove the crop but had a higher level of curd yellowing than 'Summer Love'.

'Granite' produced higher yields and heavier curds at both 29,000 plants/ha and 39,000 plants/ha compared to 'Starlight'. 'Granite' produced larger curds than 'Starlight' when grown in a 2 row configuration however in a 3 and 4 row configuration there was no significant difference in average curd size achieved by both varieties. 'Granite' achieved greater uniformity of curd weight and required less harvests than 'Starlight'. 'Granite' produced a greater number of 'yellow' curds than 'Starlight' however this was less noticeable in a 3 and 4 row configuration. When grown in a 2 row configuration 'Starlight' crops contained a greater percentage of low weight curds than 'Granite' however in a 3 and 4 row configuration 'Granite' crops contained slightly more curds below 500g in weight.

Cauliflower – Sandy soil

Plant density: Increasing plant density increased total yield and the number of marketable heads per hectare, with domestic crops planted at 39,000 plants/ha achieving increased earnings of $4510/ha when configured in three rows and $4592/ha when grown in a four row configuration. Increases in planting density from 29,000 plants/ha to 39,000 plants/ha did not significantly affect export marketable yield although minor increases were observed. The improvement in marketable yield achieved by four row crops at 39,000 plants/ha was not sufficient to counteract the increased cost of seedlings and crops grown in this configuration earned less than two row crops planted at 29,000 plants/ha. Crops configured in three rows at 39,000 plants/ha did produce sufficient increases in export market yield to achieve an increased enterprise margin of $1150/ha. The average weight of curds generally decreased with increasing planting density however curd size was not significantly affected in the majority of field experiments. The percentage of curds within the crop weighing approximately 1.0 kg (uniformity of curd weight) either stayed the same (experiments 5, 6 and 7) or decreased (experiments 1, 2, 3, 4 and 8) when planting density was increased. Uniformity of crop maturation (number of harvests and percentage of yield removed at each harvest) was not affected by increasing planting density. In general, there was a slight trend for plants grown at 29,000 plants/ha in a three or four row configuration to mature earlier than plants at the same density in a two row configuration or those grown at higher planting densities. Increasing the planting density generally increased the number of curds within the crop which were regarded as 'too small' (below 500g) but had no significant effect on the percentage of 'yellow' curds within the crop.

Planting configuration: Although not significant, cauliflower plants grown at 29,000 plants/ha tended to produce higher total yields when grown in a four row configuration compared to a 2 row configuration and at 39,000 plants/ha, the highest total yields were produced by plants grown in a 3 row configuration. Alteration of the row configuration 2 to 4 rows at 29,000 plants/ha resulted in a marginal increase in export marketable yield and number of domestic marketable curds produced per hectare which returned an extra $271/ha and $580/ha respectively. At 39,000 plants/ha, three row crops were observed to be slightly more productive than four row crops with higher total and marketable yields achieved. Increasing the number of rows per bed either had no effect on the uniformity of curd weight (experiments 4, 5, 6, 7 and 8) or decreased it (experiments 1, 2 and 3). The average size and weight of curds, uniformity of crop maturation, percentage of yellow curds and percentage of low weight curds within the crop were not significantly affected by alteration of the row configuration.

Varietal performance: No significant difference in the total yield produced or the number of marketable heads per hectare was observed between 'Summer Love' and 'Fremont' grown at all planting densities and row configurations. 'Summer Love' produced a significantly higher export marketable yield than 'Fremont'. No significant difference in curd weight, curd size or the percentage of 'too small' curds within the crop was observed between the different varieties grown at all planting densities and row configurations. 'Summer Love' produced a significantly higher percentage of curds which weighed approximately 1.0 kg than 'Fremont' at all planting densities. 'Fremont' matured more uniformly, requiring significantly less harvests than 'Summer Love' at all planting densities. In a two row configuration there was no varietal difference in the level of curd yellowing however in three and four row configurations, 'Fremont' contained significantly more yellow curds than 'Summer Love'.

The performance of 'Aviron' and 'Lisbon' was observed to change depending on the time of year they were grown. During the spring production period (August to October), 'Lisbon' produced higher yields and number of marketable heads per hectare than 'Aviron' at both 29,000 plants/ha and 39,000 plants/ha. 'Lisbon' grown during spring had a heavier average curd weight and less curds weighing below 500g than 'Aviron'. During autumn, differences between the two varieties were less apparent where no significant difference in export marketable yield, average curd size, curd weight uniformity or uniformity of crop maturation was observed between 'Aviron' and 'Lisbon'. 'Aviron' produced a significantly higher total yield than 'Lisbon' when grown at 29,000 plants/ha and produced significantly less yellow curds 'Lisbon'.

'Sirente' produced a significantly higher total and marketable yield than 'Amsterdam' at all planting densities. There was no significant difference between varieties in the number of marketable heads produced at a planting density of 29,000 plants/ha but at 39,000 plants/ha 'Sirente' produced significantly more marketable heads than 'Amsterdam'. 'Sirente' produced heavier curds than 'Amsterdam' but there was no significant difference in curd size. 'Sirente' crops had a significantly higher percentage of curds of approximately 1.0 kg and required significantly less harvests than 'Amsterdam' at all planting densities. 'Amsterdam' plants had significantly more curds less than 500g than 'Sirente' at a planting density of 39,000 plants/ha. There was no significant difference between varieties in the percentage of 'yellow' curds within crops.

Broccoli – Loam soil

Plant density: Increasing plant density did not significantly increase the total and marketable yield in experiments 1, 2 and 3. In experiment 4, total and marketable yield of 'Viper' increased significantly with higher plant density. The number of heads suitable for the domestic market was significantly greater when plant density was increased in the majority of field experiments. Increasing plant density significantly decreased the average weight of heads in all experiments. This led to a decrease in the percentage of heads within the crop which weighed more than 500g and an increase in the percentage of heads which weighed less than 300g. Achieving most heads within the crop at a weight between 300g and 500g occurred at planting densities of 44,000 plants/ha and 47,000 plants/ha for experiments 1, 2 and 3 and at planting densities of 51,000 plants/ha and 52,000 plants/ha for experiment 4. The average size of heads was either decreased or not affected by increases in planting density. Increasing planting density had no significant effect on the number of harvests required to remove the crop.

Planting configuration: Increasing the number of rows from three to four per bed at a planting density of 59,000 plants/ha significantly increased the total and marketable yield produced by plants in experiment 2 but had no significant effect in experiments 1 and 3. Increasing the number of rows from three to four per bed at a planting density of 59,000 plants/ha significantly increased the number of marketable heads per hectare in experiments 2 and 3 but had no significant effect in experiment 1. The row configuration used at 59,000 plants/ha had no significant effect on the average weight of heads or on the number of harvests required to remove the crop. Comparison between row configurations was not made at the other planting densities.

Broccoli – Sandy soil

Plant density: Increasing planting density significantly increased the total yield and number of marketable heads produced per hectare in all field experiments. Yield of heads suitable for export was observed to increase significantly with increasing planting density when plants were grown in either a 2 or 4 row configuration however significant decreases in marketable yield were observed with increasing planting density when plants were grown in a 3 row configuration. The average weight of heads was either not significantly affected or decreased with increasing planting density. As planting density increased, the percentage of heads within the crop which were greater than 500g decreased and the percentage which were less than 300g increased. This effect was more noticeable in 'Ironman' with 'Endurance' apparently less sensitive to changes in planting density. Heads harvested from experiments 1 and 2 were cut for export market specifications and therefore these crops contained a higher percentage of heads weighing less than 300g than crops in experiments 3 and 4. Increasing planting density had no significant effect on the average size of heads produced in the majority of field experiments. Increasing planting density also had no significant effect on the uniformity of crop maturation with the same number of harvests required to remove crops grown at all planting densities and row configurations.

Planting configuration: Increasing the number of rows per bed from 2 to 4 at 39,000 plants/ha, 47,000 plants/ha and 59,000 plants/ha generally decreased total and marketable yield in the majority of field experiments. The number of marketable heads produced by plants grown at 47,000 plants/ha and 59,000 plants/ha was not significantly affected when the row configuration was altered. In experiment 3, 'Endurance' at 39,000 plants/ha had a significantly lower number of marketable heads in a four row configuration compared to a two row configuration. 'Endurance' produced the same average head weight when grown in either a 2, 3 or 4 row configuration at 39,000 plants/ha, 47,000 plants/ha and 59,000 plants/ha. 'Ironman' tended to produce heavier heads when grown in a 2 row configuration at 47,000 plants/ha and 59,000 plants/ha. Alteration of the row configuration at 39,000 plants/ha, 47,000 plants/ha and 59,000 plants/ha had no significant effect on the average size of heads or the number of harvests required.

Varietal performance: 'Ironman' generally produced the same or higher total and marketable yield and number of marketable heads per hectare than 'Endurance' or 'Legacy' at all planting densities and row configurations assessed. 'Ironman' generally produced significantly heavier heads than 'Endurance' and 'Legacy'. 'Ironman', 'Endurance' and 'Legacy' produced heads of the same size at all planting densities during all field experiments. There was no varietal effect on the number of harvests required to remove crops in experiments 1, 2 and 3. In experiment 4 'Ironman' required significantly less harvests than 'Legacy' when grown at 29,000 plants/ha, 35,000 plants/ha, 47,000 plants/ha and 59,000 plants/ha.

Climatic Conditions

To determine the effect of environmental conditions on alteration of row configuration within brassica crops, field experiments were conducted over a two year period. Climatic conditions were observed to have a significant effect with conditions naturally conducive to production of cauliflower and broccoli promoting the results from high density crops. For crops cultivated at the loam soil site this occurred during summer while at the sandy soil site winter conditions were the most conducive to achieving successful high density crops. Climatic conditions experienced at the two soil type locations were substantially different. At the loam soil site crops experienced an average maximum temperature of 23℃ during summer and 16℃ during winter with an annual rainfall of 856 mm per year. The best yields from high density crops containing the maximum number of curds/heads within the desired market specifications at this location were achieved during the warmer months of production (November to March). Temperatures at the sandy soil site were generally higher with an average maximum temperature of 28℃ during summer and 20℃ during winter with an average annual rainfall of 678 mm. The best yields at increased planting densities at this location were achieved within a three row configuration during the cooler months of production (April to October) when optimal growing conditions are experienced.

Table 50: Recommended planting configurations for cauliflower and broccoli produced on loam and sandy soil types.

Soil type	Cauliflower			Broccoli		
	Plant density (plants/ha)	Number of rows	Best variety and production period	Plant density (plants/ha)	Number of rows	Best variety and production period
Loam	39,000	4	Monarch and Summer Love November – April	51,000	2	Viper December – February
Sand	32,000 to 39,000	3	Lisbon and Sirente April – October	47,000	2	Ironman April – October

Discussion

An aim of this project was to identify the best planting density and row configuration for production of cauliflower and broccoli in Western Australia. However the best planting configuration for individual producers will depend largely on the product specifications required by export and domestic markets and existing machinery resources. Detailed information had been provided in the results section so individual producers can decide which planting density is most likely to suit their current production system.

Increasing planting density on both loam and sandy soil types was shown to be of economic benefit to producers through increases in yield and the number of marketable curds/heads produced per hectare. However the curd/head weight and to a lesser extent the size, were affected with a general decrease in curd/head weight and size observed with increasing planting density. Consumer preference towards smaller cauliflower curds and broccoli heads has increased in recent years due to decreased family size and the move towards convenience foods. Production systems which utilise higher planting densities to produce a greater number of smaller curds or heads are likely to suit the trend towards smaller product size and achieve better economic returns for producers.

Soil type and climatic conditions had a significant effect on the ability of cauliflower and broccoli plants to achieve required product weight and size at increased planting densities. Plants grown on loam soils which had higher water holding capacity and fertility were able to achieve heavier and larger curds/heads at increased densities than those produced by plants grown on the sandy soils. Plants grown on sandy soils at high densities displayed increased difficulty in accessing water and nutrient resources. Periods of the year when climatic conditions are naturally conducive to production of cauliflower and broccoli resulted in the most significant increases in marketable yield and number of marketable curds/heads at increased planting densities. Extreme temperatures or increased pest and disease pressure due to climatic conditions increased the already competitive environment within high density plantings, reducing the ability of plants to reach their true yield potential. Broccoli plants were observed to be naturally more competitive and have lower nutrient and water demands than cauliflower allowing crops to be grown at much higher planting densities. While cauliflower crops grown at a planting density of 32,000 plants/ha to 39,000 plants/ha produced the best results, increased yields and heads within acceptable size and weight specifications were achieved by broccoli grown at planting densities ranging from 39,000 plants/ha to 51,000 plants/ha.

Increasing the number of rows per bed was shown to be an effective method of increasing planting density. The ability to increase planting density by decreasing spacing within a two row configuration will quickly become limited as inter-plant competition increases. By reducing the between row spacing (increasing the number of rows per bed to three or four) resources such as light and nutrients are more effectively utilised permitting higher planting densities to be achieved. Results from this project have indicated improved yields of cauliflower and broccoli and greater economic returns can be achieved by increasing planting density within three and four row configurations. Soil type was shown to have an influence on the best row configuration to achieve increases in planting density. On loam soils using a four row configuration produced the best results within high density crops however on sandy soils three row configurations were more successful. The ability to successfully increase planting density by alteration of row configuration means that planting machinery used for production of high density crops such as lettuce could also be utilised for the production of cauliflower and broccoli. This will facilitate the introduction of lettuce as a rotational crop for cauliflower and broccoli in the south west region of Western Australia and also assist the production of lettuce crops on sandy soil types.

In the current production system, cauliflower curds and broccoli heads are harvested by hand as they mature. This cultural system is labour intensive and harvesting costs contribute as much as 40% to a crop's total variable costs. Agronomic factors which influence the uniformity of cauliflower and broccoli maturation are currently being investigated by the Department of Agriculture and Food WA (DAFWA) in project VG02051. This work aims to compact the spread of crop maturity, reducing the number of harvests required to completely remove a crop. Increasing planting density and alteration of planting configuration has been shown to improve the uniformity of broccoli head maturation (Sorensen and Grevsen, 1994; Aldrich *et al.*, 1961). To confirm these results in broccoli and determine if a similar effect would occur in cauliflower, the number of harvests required to remove crops was assessed within a range of planting configurations. Increasing planting density and alteration of row configuration during this project did not significantly affect the uniformity of crop maturation within cauliflower and broccoli crops grown on both a loam and sandy soil type. However high density plantings managed using techniques developed during project VG02051 are likely to be well suited to a mechanised harvesting system which would reduce the cost associated with manual labour.

Previous literature (Salter and James, 1975) indicates that genotype is likely to have a significant effect on the performance of varieties grown at increased planting densities. Characteristics such as frame size, ability to intercept light and self-covering ability will affect plant performance when increased planting density intensifies plant competition for available resources. In seasonal periods where a direct comparison was made between large and small framed varieties a distinct trend was observed. Varieties which had large plant frames tended to produce larger and heavier curds than the smaller framed variety at low planting densities however when density was increased difference in curd size and weight became less obvious. The more vigorous large framed varieties were unable to reach their full yield potential at higher planting densities due to increased inter-plant competition. Significant differences in harvest characteristics were observed between other varieties without substantial frame size differences however they generally occurred at all planting densities and were not altered by a change in planting configuration. A number of varieties were identified for each seasonal period which produced superior harvest characteristics but displayed no interaction between genotype and planting density.

Changes to the fertiliser and irrigation programs for these trials have been necessary to ensure plants in the high density treatments received adequate nutrition and water. The successful adoption of this research by industry will require producers to appropriately increase application levels of fertiliser and carefully monitor soil moisture content in order for high density plantings to realise their potential. The close proximity of plants within high density plantings will require more intensive management of pests and disease to prevent loss of yield. Pests and disease once established are likely to be difficult to control thus careful monitoring of crops will be required to prevent pests such as Diamondback moth (*Plutella xylostella*) becoming a problem.

Cultivating cauliflower and broccoli in three and four row configurations may be beneficial for effective utilisation of land and machinery however it can create difficulty in cultural operations such as covering and harvesting. Cauliflower plants grown in widely spaced rows provide better access for covering, an important process in preventing curd yellowing. White shadecloth which permitted 50% light transmission prevented curd yellowing and maintained yield similar to that achieved by curds which had been manually covered. Water transmission through the shade cloth to the plants did not appear to be affected by the shade cloth and an increase in pest or disease levels were not observed. Covering of cauliflower crops with shade cloth, which could be mechanically deployed over the plants, could be a viable alternative to manual covering which currently represents a significant cost to the management of cauliflower crops.

Recommendations

Cauliflower crops in Western Australia are traditionally planted at a planting density of 29,000 plants/ha. This planting density can be increased up to 39,000 plants/ha to achieve improved yields of product suitable for both domestic and export market specifications. On loam soils, configuring high density crops in four rows will provide the greatest increases in enterprise margin while on sandy soil types, three row configurations should be used to maximise enterprise margin. Broccoli crops grown on loam soils should be planted at densities ranging from 39,000 plants/ha to 52,000 plants/ha in either a two, three or four row configuration to achieve the highest yields of heads suitable for both export and domestic market specifications. On sandy soil types, the most productive configuration for broccoli will be a planting density of 47,000 plants/ha arranged in two rows per bed.

Alteration of the row configuration at a planting density of 29,000 plants/ha from two rows to four will provide increases in yield and profit margin in cauliflower crops grown on both loam and sandy soil types. Increasing the number of rows per bed is also an effective way to increase planting density allowing for greater yields of cauliflower and broccoli to be achieved whilst maintaining product quality. The ability to successfully produce cauliflower and broccoli crops in a range of planting configurations allows producers to use planting machinery suitable for a range of crops resulting in a greater return on capital invested in machinery.

Irrigation and nutrition programs will need to be modified to ensure that plants grown at increased planting densities are not limited by nutrients or water. In particular, the level of major nutrients such as phosphorus and nitrogen may need to be increased depending on the planting density chosen. Soil moisture monitoring equipment should be used within crops to schedule irrigation so that high density crops do not become water stressed. Increased pest and disease pressure was not observed within high density crops during this project however consistent monitoring for pests and disease should be incorporated as standard crop management protocol. This is particularly important in high density crops as the close proximity of plants will make post-infection / infestation control more difficult.

Environmental conditions and cultivar choice will play an important role in the success of high density brassica crops. The best yields will be achieved by high density crops cultivated during climatic conditions which are most suitable for the production of cauliflower and broccoli crops. Extreme temperatures and increased pest and disease pressure during particular seasons will increase the difficulty in achieving consistently high yields within high density crops. The most suitable varieties for high density crops will depend on the production season and crop location however at the loam soil site ‘Summer Love’, ‘Monarch’ and ‘Granite’ were all shown to perform well within high density plantings. At the sandy soil site differences in variety were not as apparent with ‘Summer Love’, ‘Fremont’, ‘Aviron’, ‘Lisbon’ and ‘Sirente’ all performing well at increased planting density.

Although crop maturation uniformity was not improved solely by increasing planting density, agronomic techniques for reducing the spread of harvest have been developed in project VG02051. Covering of high density crops using white shade cloth with 50% light transmission prevents curd yellowing and removes the need for labour to cover by hand which contributes significantly to harvesting costs. These techniques used in conjunction with high density plantings arranged in three and four row configurations are likely to suit an intensively managed system where crops are harvested by machine.

Technology Transfer

Publications:

Stirling, K.J. and Lancaster, R.A. (2004) Alternative planting configurations influence cauliflower development. *Acta Horticulturae* 694: 301 – 305

Prideaux, B. (2005) *'Trials aim to lift cauliflower output'* - April 2005 Issue of Good Fruit and Vegetables

Prideaux, B. (2006) '*Close formation cauliflowers could change industry face'* – April 2006 Issue of Good Fruit and Vegetables

Walker, C. (2006) *'Alternative plantings trialled on cauliflower crops'* – August 2006 Issue of Vegetables Australia

Reeve, J. (2004) 'Way open for smaller curds' – September 2004 WA Horticulture Liftout in The Countryman

Stirling, K.J. (2004) Alternative planting configurations influence cauliflower development – September 2004 edition of Better Brassica

Lillis, E. (2005) 'Four row could be the go' – January 2005 Manjimup-Bridgetown Times

Reeve, J. (2005) 'Density Trials' – September 2005 WA Horticulture Liftout in The Countryman

Stirling, K.J. and Lancaster, R.J. (2005) Alternative Planting Configurations Influence Cauliflower Development. DAFWA Biennial Horticultural Conference

Reeve, J. (2006) 'Cauli trials flower' – January 2006 WA Horticulture Liftout in The Countryman

Stirling, K.J. (2006) Density Trials – March 2006 edition of DAFWA Agmemo publication (sent to all producers in WA)

Stirling, K.J. (2006) More than two rows could be the go! – April 2006 edition of Better Brassica

Stirling, K.J. (2006) Density Trial Progress Report – October 2006 edition of Better Brassica

Radio Interviews:

ABC Rural Report – Progress report on results so far (19 January 2005)
ABC Rural Report – Progress report on results so far (24 January 2006)

Field Walks:

Field walk for Trial 1 at Manjimup (16 September 2004)
Field walk for Trial 1 and 2 at Manjimup (27 January 2005)
Field walk for Trial 2 at Medina (17 March 2005)
Field walk for Trial 4 at Manjimup (17 June 2005)
Field walk for Trial 6 at Manjimup (25 January 2006)
Field walk for Trial 7 at Manjimup (12 April 2006)
Field walk for Trial 6 at Medina (5 May 2006)
Field walk for Trial 8 at Manjimup (14 June 2006)
Field walk for Trial 8 at Manjimup (25 July 2006)
Field walk for Demonstration at Manjimup (31 January 2007)
Field walk for Demonstration at Manjimup (28 March 2007)

Presentations at meetings/seminars/workshops:

Presentations on the general scope of the project and regular updates of project results occurred at:
Regional brassica workshop in Wanneroo (August 2004)
Regional brassica workshop in Manjimup (August 2004)
Manjimup Horticulture Research Institute Field Day (March 2005)
Medina Research Station Field Day (July 2005)
DAFWA Biennial Horticultural Conference (September 2005)
Regional brassica workshop in Manjimup (June 2006)
Regional brassica workshop in Wanneroo (July 2007)
Regional brassica workshop in Manjimup (July 2007)
Vegetables WA regional meeting in Manjimup (August 2007)

Regular updates on the progress of this project were provided during on-farm grower group meetings which were held every 3 months (2003 – 2007)

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