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ROW SPACING AND PLANT POPULATION IN SUNFLOWER PRODUCTION

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QUEENSLAND DEPARTMENT OF PRIMARY INDUSTRIES

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ROW SPACING AND PLANT POPULATIONS IN SUNFLOWER PRODUCTION

1. INTRODUCTION:

Future expansion of the sunflower (*Helianthus annus*) industry in Australia is dependent on increased productivity of the crop under dryland farming conditions together with increased yield stability. Better adapted varieties and improved crop husbandry will have to be developed if the industry is to expand.

Sunflower is a short season crop with a growing period of 3½ - 4½ months. The crop gives good yields on a wide range of soil types, although poorly drained and shallow or very acid soils are not suitable. A recognised characteristic of sunflower heads, accounting for both the botanical and common names of the plant, is their facing towards the sun throughout the day. This process ceases when anthesis or pollen shedding begins.

Sunflowers are often grown in Queensland under high evapo-transpiration, erratic rainfall and in many instances shallow soils. These conditions contrast with the more favourable conditions of other countries such as the northern United States where reliable precipitation provides substantial reserves of moisture. Nevertheless, sunflowers have shown themselves to be extremely adaptable and good yields have been achieved in many parts of the State.

Plant arrangement, plant population and row spacing are variables which can be manipulated by the sunflower grower during planting with conventional machinery. Variation of row spacing alters not only plant arrangement but also the opportunities for cultural practices as inter-row cultivation, fertilizer banding and irrigation.

This paper reviews existing literature and Departmental research on sunflower population and row spacing and considers how optimum plant populations can be efficiently utilized. It also describes a small survey of sunflower growers in the Jondaryan Shire of the Darling Downs.

2. PLANT COMPETITION:

Row spacing and intra-row plant spacing are the two components of plant arrangement within a crop. The options range from equidistant plant spacing to rows of varying width. Rows may also be arranged as twin or skip rows. A new plant arrangement, as yet untested, can be described as cluster planting and has been suggested by Myers and Foale (1978).

Altering plant arrangement whilst maintaining a constant population alters the dimensions of the space available to the plant roots and to the plant tops. Myers and Foale identified the effects of these changes as -

* changed light distribution patterns.

* changed root development patterns affecting moisture and plant nutrition.

* changed advection effects - changes in partition of net radiation between plant and soil, thereby affecting canopy temperature, soil evaporation.

* effects on stem elongation through light quality and uniformity of flowering.

Plants compete for water, light, nutrients, oxygen, carbon dioxide and in the reproductive phase, agents of pollination and dispersal. Other factors, such as temperature and humidity, are not commodities in finite supply and hence are not the subject of competition. Water, nutrients and light are the factors most commonly deficient, but in rapidly photosynthesising crops, carbon dioxide may also be depleted by competing plants. Competition for soil oxygen may be of significance in poorly structured soils.

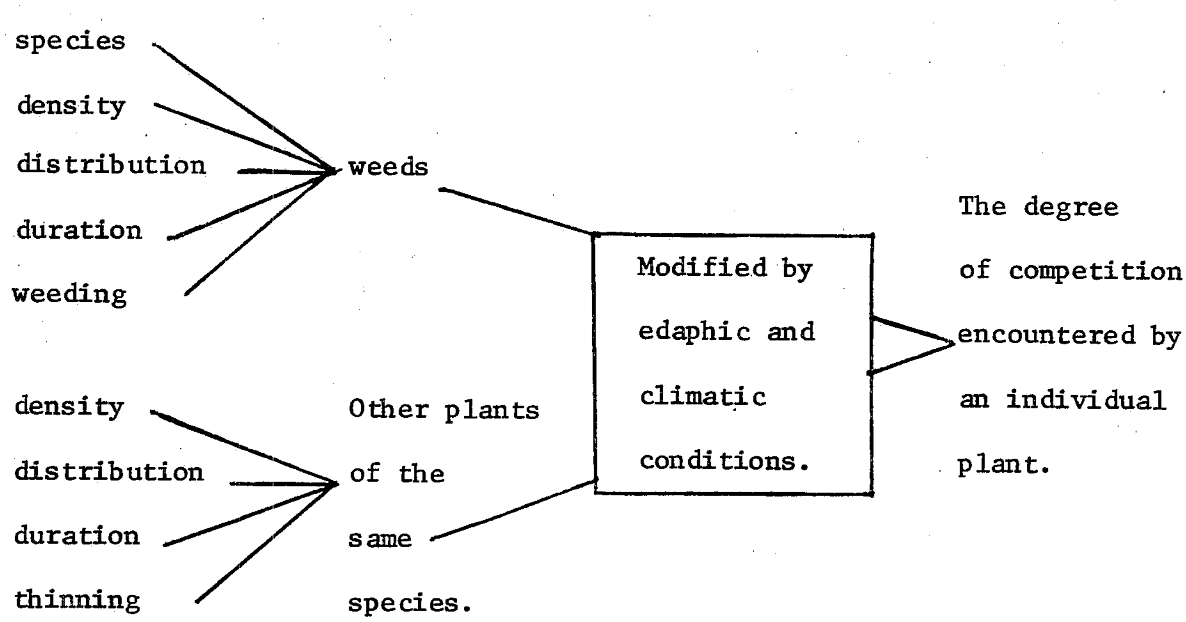
There have been a number of definitions of plant competition. Donald (1963) states that "competition occurs when each of two or more organisms seeks the measure it wants of any particular factor or thing and when the immediate supply of the factor or thing is below the combined demand of the organisms". Many of the factors which plants compete for can be found as a pool of material from which competitors draw their supplies. If all the plants in the community are nearly equal in competitive ability, they will tend to share equally in the supply until it is exhausted and then, simultaneously to suffer the effect of depletion of the pool.

Donald also commented that competition may also be influenced by the exudation of toxins from a plant, which depress the growth of a neighbour. Bleasdale (1960) concluded that plants compete for water, light and nutrients either simultaneously or in rapid succession, but since plant growth integrates this situation, plant weight can be used as an index of competition. Similarly, seed yield of a sunflower plant is an end product of a system of plant competition (Radford 1976).

Bleasdale (1960) summarised diagrammatically some of the factors determining the degree of competition encountered by an individual plant. This has been presented in Figure 1.

FIGURE 1

Schematic presentation of the competition encountered by an individual plant - after Bleasdale (op. cit.)



The magnitude of the contribution of any one factor could be expected to vary greatly because of its dependence on other factors. For instance, the density of weeds could be expected to have little effect on a crop if their duration was short.

In any consideration of plant populations, the prime factor governing the optimum plant density within any particular unit area will be the ability of a single plant to compete with its neighbouring plant. If plant population is high, then the demand for any limiting nutrient may exceed supply, and plant growth could be retarded. If nutrient supply exceeds demand, then the nutrient supply is not being fully utilised. Consequently, in sunflower production, it is necessary to derive the plant population that optimizes yield and oil content.

3. RECENT RESEARCH ON SUNFLOWER ROW SPACING AND POPULATION:

During the late 1960's and early 1970's, B.J. Radford, Agronomist, Toowoomba conducted a detailed and comprehensive study of sunflower row spacing and population on the Darling Downs under both rainfed and irrigated conditions.

Radford (1976) investigated plant establishment procedures for sunflower crops grown on the black earth soils of the Downs. His study involved an examination of the effects of plant population on the growth and yield of both irrigated and dryland sunflower production.

Following these studies, Radford asserts that:-

* under weedfree conditions, narrow row spacings (30 cm) produce the highest yields in both irrigated and dryland crops.

* row pairing shows no advantage over the equivalent evenly-spaced rows under dryland conditions.

* the optimum established plant population with respect to yield and oil content is 100 000 plants/ha for irrigated sunflowers and 50 000 plants/ha for dryland crops.

Plant Population x Row Spacing Interactions.

In Radford's irrigated trials, there was only one significant interaction between these parameters. This was the number of heads at harvest in 1969 - 70. It occurred because the level of variability was low after thinning to precise plant populations.

In the rainfed trials, and under the low-yielding conditions experienced in 1969-70, low plant populations in narrow rows produced the highest yields and number of achenes per head. However, except under the extreme conditions of that year, population - row spacing interactions were of no consequence.

Effects of Plant Population.

Highest yield levels were attained at 50 000 to 100 000 plants/ha in the irrigated trials, and at 37 500 to 62 500 plants/ha in the rainfed trials.

In the 1972-73 irrigated trial, unlodged or harvestable yield showed a steeper decline than total yield as population increased because the proportion of lodged plants increases with plant population. Incidence of lodging was negligible in the other trials.

All three components of yield - achene weight, number of achenes per head and head population at harvest - varied with plant population. Achene weight and number of achenes per head declined as plant population increased in each trial. Plant mortality was negligible at all populations tested in all four rainfed trials, but in the irrigated trials, plant mortality percentage increased with population.

The response of oil content to changes in plant population showed no clear pattern. Within the population ranges tested, low populations significantly reduced oil content in four out of seven trials and high population significantly reduced oil content in two out of seven trials.

Effects of Row Spacing.

Yield declined significantly with increase in row spacing from 30 to 108 cm in five out of seven trials. The only yield component affected significantly was number of achenes per head, which declined with wider row spacing in three out of seven trials.

Effects of Row Pairing in Rainfed Trials.

Paired row treatments yielded no differently from their corresponding evenly-spaced row treatment. Oil content was not affected by row pairing.

Conclusions.

Radford concluded that for highest yield and oil percentage, populations of 50 000 to 100 000 plants/ha appear suitable for irrigated crops and 40 000 to 60 000 plants/ha for rainfed crops in the Darling Downs environment. Yield reduction due to wide row spacing appears likely over a wide range of environmental conditions. Such reductions in these experiments were due mainly to reductions in number of achenes per head.

Radford's results indicate that row spacing for both irrigated and rainfed crops should be no wider than 36 cm under weed free conditions. Where mechanical weed control is necessary, row spacing should be as narrow as possible while still permitting the passage of inter-row cultivators.

Research into the influence of plant density on the yield and oil content of dryland sunflowers was recently conducted by Jessop (1977) in the Wimmera district of Victoria. In his experiments using three times of sowing (mid-September, mid-October and mid-November) with plant densities of 25 000, 50 000, 75 000 and 150 000 plants/ha, the highest grain and oil yields were obtained from a November sowing and a plant density of 25 000 or 50 000 plants/ha. His results have been presented in Table 1.

The results show that plant density up to 50 000 plants/ha had no effect on grain yield, but higher plant densities reduced yields. These results support those of Radford (op. cit.) and it is not until the extremely high population of 150 000 plants/ha that yield starts to drop back. Once again there is evidence of the population/yield plateau effect at populations up to 75 000 plants/ha.

TABLE 1

Mean effect of time of sowing and plant density

Treatments	Grain Yield (t/ha)		Oil Content (%)		Grain Weight g 1 000	
	Exp 2	Exp 3	Exp 2	Exp 3	Exp 2	Exp 3
Time of Sowing						
September	0.95	1.11	42.2	42.6	45.5	47.7
October	1.10	1.11	40.7	43.5	44.6	44.2
November	1.17	1.46	45.9	44.7	61.4	44.7
Plant Density (Plants/ha)						
25 000	1.18	1.42	43.0	44.1	64.2	54.6
50 000	1.18	1.43	43.6	44.2	50.2	45.3
75 000	1.05	1.19	42.4	43.1	43.7	45.0
150 000	0.78	0.87	42.7	43.2	38.7	37.1

Source: Jessop (op. cit.)

4. SUNFLOWER POPULATION RECOMMENDATIONS:

At present, two different approaches can be used in preparing sunflower population recommendations. The blanket recommendation which is used by Radford (op. cit.) and an adjustment-factor technique.

4.1 The Blanket approach

This method does not adjust the population recommendation for environmental changes, other than for periods of extreme stress. The blanket approach entails giving one population recommendation for a fairly homogeneous environment such as for raingrown crops on the Darling Downs. Radford (pers. comm.) considers 50 000 plants per hectare for raingrown crops to be a suitable blanket recommendation for the Downs region as it is on or near the yield plateau under all conditions, the plants themselves at this density being very nearly capable of making the necessary adjustments within the range of environments likely to occur.

While recognising that for each planting it is desirable to have a specific ideal population to work towards, Radford feels that this would present most growers with unnecessary complications.

* The sunflower crop as we know it at present is very uneven. Presumably there is an unevenness of individual plant response to variations in plant arrangement. Thus extremely accurate population recommendations are not possible. This situation may change with the advent of the more uniform hybrid sunflowers.

* The planting equipment in use by the majority of growers lacks precision and, although there are several methods for improving evenness of seed drop, plant stand is still uneven. The effect of uneven plant stand probably reduces yield. This effect probably becomes worse at low plant populations and could offset any advantage in using a low population, even though that population has been shown to be optimum for the given environmental conditions by means of a field trial with uniformly-spaced plants.

* The high variability of the summer rainfall pattern, and the reduced significance of stored soil moisture for a summer crop as compared with a winter crop tend to make highly accurate summer crop populations very difficult.

* The raingrown trials indicated that the extreme range of ideal populations likely to be required on the Downs is only 37 500 to 62 500 plants per hectare. These trials experienced extremes of both wet and dry years. Furthermore, irrigated population trials appeared to have reached maximum yield by 50 000 plants per hectare.

4.2 The Adjustment-Factor Approach

The adjustment-factor approach is a population recommendation technique that is used by some American seed companies. The approach is based on the assumption that sunflowers have a definite population response to available moisture in terms of total yield. Often moisture is a limiting factor even though sunflowers are considered drought tolerant, and after establishment can withstand drought stresses better than many crops.

The adjustment-factor approach involves computing an ideal population dependent upon the various factors which influence the anticipated available moisture. The information used is the anticipated precipitation, the plant population adjustment factor lists, and the ideal population computation table. Examples of the latter two items have been attached as Appendices 1 and 2.

While the adjustment-factor method is the most accurate recommendation technique, its use in applied Australian agriculture is questionable. The data required to use the method is currently unavailable to Australian farmers due to the intense variability of summer rain - long term rainfall records provide poor prediction of summer rainfall expectation on the Darling Downs.

Most farmers are also unaware of their plant populations after emergence, and hence any accurate population recommendation could be affected by a low emergence.

The method tends to become too complex, and most farmers prefer a simpler approach. Such a method would probably be more desirable if a yield/population peak could be established; however, Radford's work shows that the yield/population relationship tends to plateau, indicating that precise population accuracy is not critical.

The blanket recommendation approach is more suitable, with some adjustment being considered for extremes of soil moisture.

5. SUNFLOWER PLANT DISTRIBUTION:

Another factor which affects yield is the position of one plant relative to its neighbour. This aspect has been considered by Remussi *et al*. (1974). They carried out investigations on the effects of sowing uniformity on sunflower yield.

Sunflower was sown in rows 0.7 m apart, but with different distances among plants on the basis that six seeds would be sown every 1.2 m, so that the number of plants per unit area was the same (70 000 plants/ha) in all the treatments (Table 2).

TABLE 2

Distribution of plants in each treatment

No. 1	20	20	20	20	20	20 cm between each seed
No. 2	10	30	10	30	10	30 cm between each seed
No. 3	10	20	30	10	20	30 cm between each seed
No. 4	10	10	40	10	10	40 cm between each seed
No. 5	5	5	5	5	50	50 cm between each seed

Source: Remussi *et al* (op. cit.)

The results obtained over two years showed that uniform sowing gave the best yield (Table 3). Plant losses between sowing and harvesting, head diameter and yields were obtained during the first year, but only yield was recorded during the second year.

TABLE 3

Yield (kg/ha) according to treatment and year

	1971/72	1972/73	Average Yield	Classification
No. 1	2 347	2 455	2 401	Uniform
No. 2	1 942	2 295	2 118	Scarcely uniform
No. 3	1 987	2 227	2 107	Scarcely uniform
No. 4	1 775	1 637	1 706	Non-uniform
No. 5	1 862	1 785	1 823	Non-uniform

Source: Remussi *et al* (op. cit.)

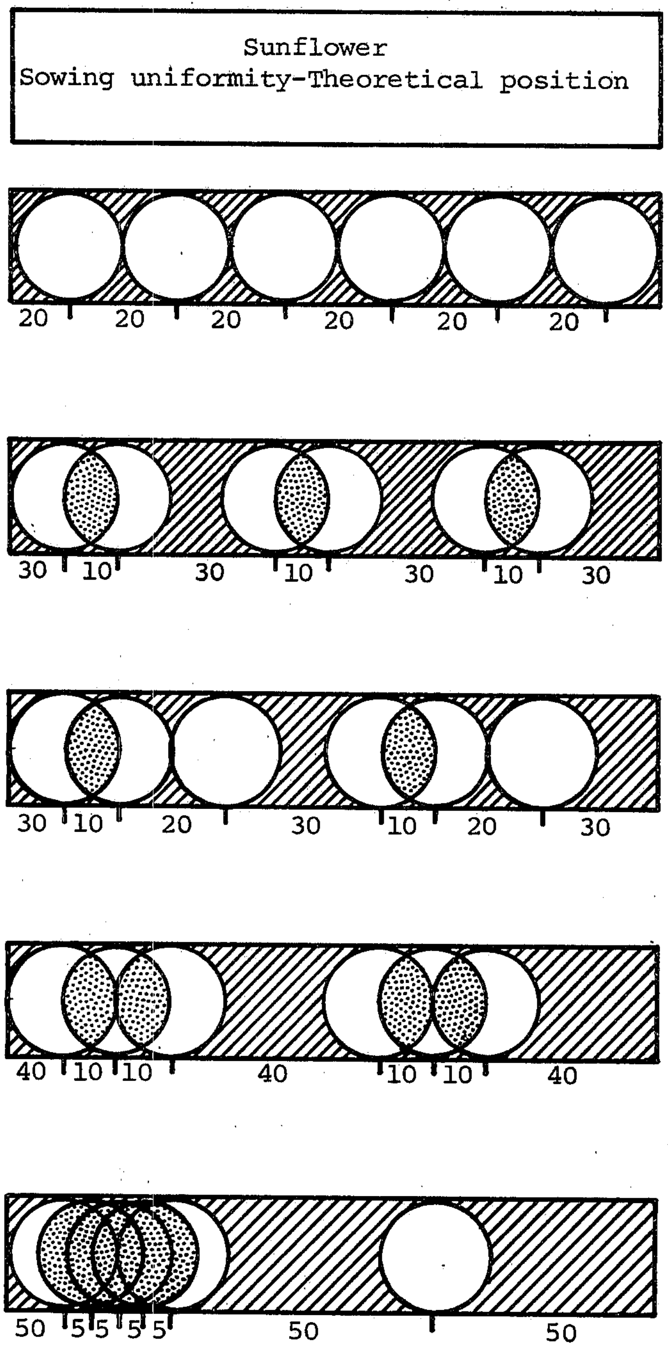
The researchers also found that the smallest head size was obtained in treatments in which the plants were closer, and the largest head size in treatments with the most growing space between plants.

In figure 2, plants have been outlined supposing that each circle of 0.2 m represents the area occupied by the plant (roots and foliage). Theoretically "superimposed" and "unavailable" areas can be observed. The "available" area for each plant is the area within each circle.

The values obtained (Table 4) show that when the "superimposed" and/or "unavailable" areas increase, yields decrease considerably. The yield was highest in the uniform planted treatment which had 100% available area without "superimposed" or "unavailable" areas.

FIGURE 2

Theoretical surface area for plants



Treat-ment	AREA A	AREA S	AREA U	% Yield	% Waste
1	100	0	0	100	0
2	50	25	25	88.9	11.1
3	66	17	17	85.5	14.5
4	33	33	33	69.0	31.0
5	25	50	25	74.9	25.1

A: available S: superimposed U: unavailable

Source: Remussi _et al_ (op. cit.)

TABLE 4

Surface, yield and mean waste percentage, 1971/72 and 1972/73.

Treatment	Surface %			Yield		Waste		Classification
	Available	Unavailable	Superimposed	kg/ha	%	kg/ha	%	
No. 1	100	0	0	2 401	100	0	0	Uniform
No. 2	50	25	25	2 118	88.3	280	11.7	Scarcely
No. 3	66	17	17	2 107	87.8	291	12.2	Uniform
No. 4	33	33	33	1 706	71.1	692	28.9	Non-
No. 5	25	50	25	1 823	76.0	575	24.0	Uniform

Source: Remussi et al (op. cit.)

Remussi's findings clearly show that uniform sunflower planting is necessary to obtain the best yields. Observations in Australia have tended to support these findings.

6. PLANTER TYPES AND SEED DISTRIBUTION:

Taylor (1978) reported on work at Biloela Research Station in Central Queensland to test the effects of presswheels and uniformity of plant stand on establishment and seed yield of sunflowers. Trials were established in 1975 and 1976 on a Callide alluvial medium clay loam. Plant stands obtained with a Shearer combine with and without presswheels were compared with stands established with the combine by planting at heavier rates and hand-thinning to a more uniform plant distribution at the same population. These treatments were compared with an IHC 18 precision planter.

Seed yield increased linearly as plant uniformity increased in both years. This increase occurred at mean seed yield levels of 2 257 kg/ha and 836 kg/ha in 1975 and 1976, respectively. Although stand uniformity with the precision planter was greater than that with the combine, it was less than that of the hand-thinned treatments in 1976 and had a corresponding lower seed yield.

In 1977, the Queensland Graingrowers Association conducted an assessment of a number of different planters (O.W. Duncan pers. comm.) to compare precision planters and traditional combines. Combine, plate and pneumatic planters were compared and the results are illustrated in Figure 3.

A plant spacing of approximately 25 cm was desired. The planting with a normal combine resulted in only 19% of the seeds being dropped in the desired 15 - 30 cm interval. It is obvious that the combine dropped the seeds in clumps.

The plate planter was little better than the combine - only 26% of the seeds fell in the desired 15 - 30 cm interval. Where number 1 seed was used on a traditional plate planter using plastic plates imported from U.S.A., the pattern was little better with 70% of the seed still outside the desired interval.

The pneumatic Nodet-Gougis precision planter produced vastly superior results, and 70% of the seeds fell in the desired 15 - 30 cm interval.

Figure 3 - Graphs of planter type - seed pattern relationships. Note: the desired placement area is the 15 - 30 cm interval.

COMBINE PLANTER-SEED SIZE NO.2.

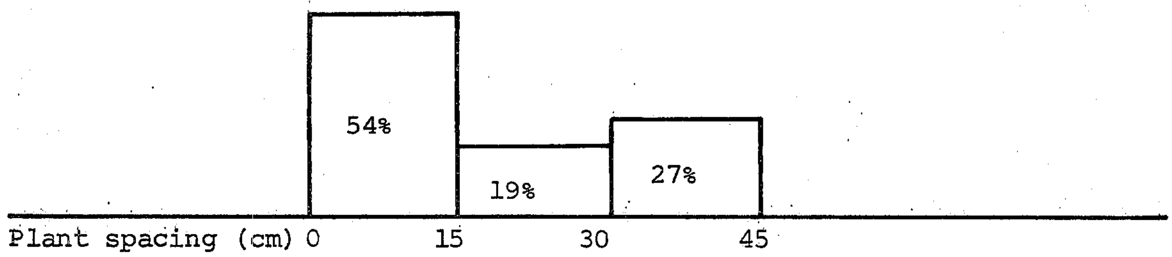


PLATE PLANTER-SEED SIZE NO.2.

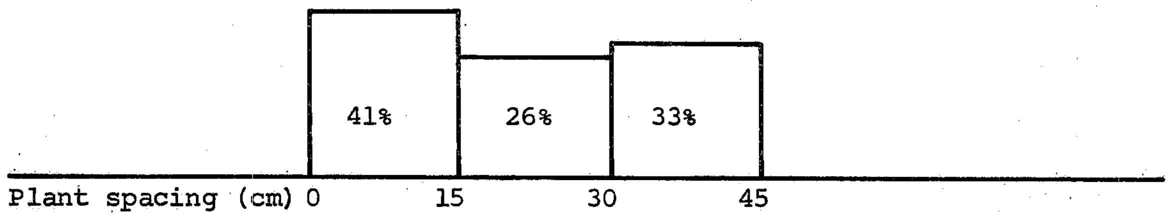
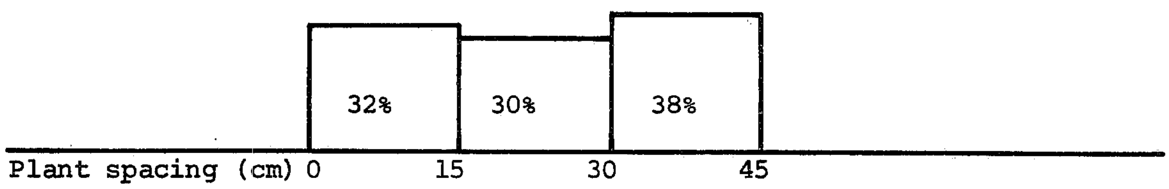
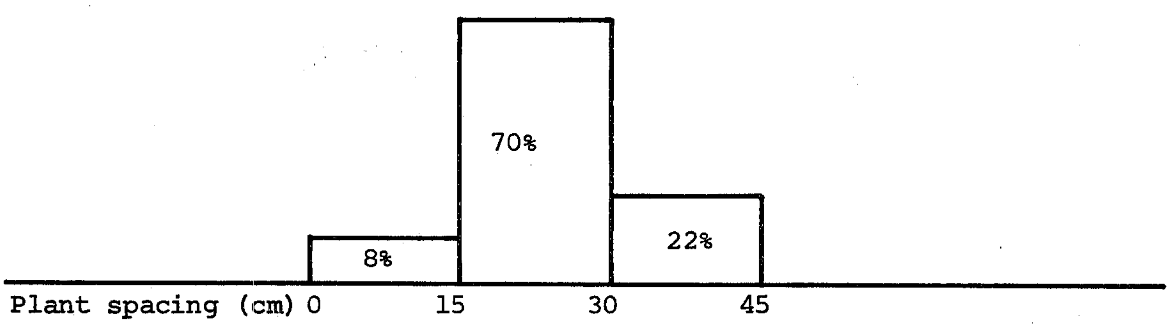


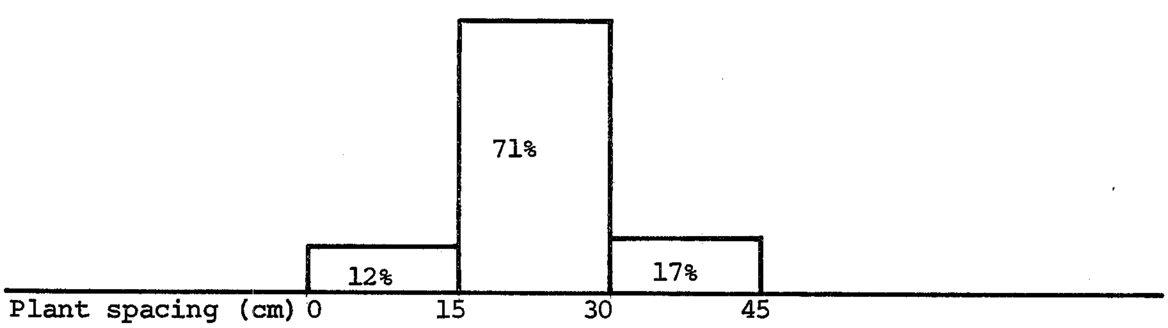
PLATE PLANTER PLASTIC PLATES-SEED SIZE NO.1.



PNEUMATIC PLANTER-SEED SIZE NO.1.



PNEUMATIC PLANTER-SEED SIZE NO.1.



As uniform sunflower planting obtains better yields, and precision planters are significantly more accurate in seed placement than the traditional combine, precision planted sunflower crops should outyield combine planted crops. Farmers claim that precision planted commercial sunflower crops on the Darling Downs yield 15 - 20% higher than crops planted through a combine.

7. FARM SURVEY:

The farm survey was conducted in the Jondaryan Shire in March-April, 1978 and consisted of two parts. The first part involved questioning 20 growers to determine their current planting practices, their attitude towards precision planters, and optimum planting populations. The second part involved a small quantitative study of three sunflower crops - a combine planted crop, a semi-precision planted crop and a precision planted crop.

7.1 Farm Survey Findings

The major findings of the farm survey are:-

* Sunflower is a relatively new crop on the Darling Downs, and over half of the farmers questioned were growing it for the first time.

* Farmers planting with precision or semi-precision planters estimated yield increases of between 15 - 20% over combine planted crops.

* 85% of farmers interviewed used a seed planting rate to determine their sunflower stand; the remaining farmers aimed for a plant population.

* Nearly all farmers were unaware of the optimum plant population and row spacing. Only one farmer had experimented using different plant populations.

* 60% of the farmers questioned had planted sunflower using a combine. Many of these were quite happy with the performance of the combine and said that the expenditure required to purchase more sophisticated planting equipment was not justified. The remainder said that if sunflower became an important part of the cropping programme, and this was dependent on markets, rainfall and weeds, serious consideration would be given to the purchase of more sophisticated planting equipment.

* Farmers who had planted with both combine and precision planters were much happier with the results obtained from the precision planters.

* The row width used varied between 72 cm and 90 cm. The width used was largely dependant on the planting machinery used. Row spacings in combine planted crops can only be changed in increments of 18 cm.

* Most farmers felt that they had planted too thinly and were receptive to plant population information.

7.2 Sunflower Population Counts

The second part of the survey was an attempt to quantify the effect of planter type on sunflower plant stands. The crops surveyed were late planted crops - February planting - and all had suffered seedling damage from sunburn, false wire-worm, earwigs and moisture stress. Consequently, it was impossible to determine whether gaps in the plant stand had been caused by the planter or problems at emergence. However, the results are considered indicative of what could be expected under normal commercial conditions.

Three sunflower crops - combine planted, semi-precision planted using Covington metering units, and precision planted using an IHC Cyclo Air planter - were studied. Sunflower plant spacing was measured over four 10 metre rows. Observations were made on the head size and plant distribution.

An arbitrary score system was used to indicate plant distribution. A plant stand that had a very even plant distribution i.e. all intra-row plant spaces the same, scored ten. A very uneven plant stand i.e. all intra-row plant spaces different, scored zero. The results of the observations have been recorded in Table 6.

TABLE 6

Results of field observations on planter types

	Planter Type		
	Combine	Covington	Precision Planter
No. of plants in 40 m	102	81	148
Average plant spacing (cm)			
Row 1	28	35	26
Row 2	40	56	24
Row 3	39	52	26
Row 4	36	41	22
Widest gap between plants (cm)			
Row 1	155	150	95
Row 2	115	138	90
Row 3	105	125	88
Row 4	98	120	65
Average	118.25	133.25	84.5
Distribution score (out of 10) Averaged over 4 rows	7.1	7.3	8.5
Head evenness	Fairly even but large heads adjacent to gaps	Fairly even	Heads small but very even
Estimated plant population per hectare	39 200	33 000	42 600
Row spacing (cm)	70	75	90

The precision planted crop was superior to the other two crops in both plant spacing and plant distribution. The precision planted crop did not suffer from having extremely wide gaps between some plants. In 40 metres of row, the widest gaps were 95 cm. The head size was very even, although the higher plant population tended to produce small heads.

The combine and semi-precision plantings produced equivalent crops in terms of plant spacing and plant distribution. The combine planted crop was an excellent stand of sunflower and showed that a little care at planting, particularly reduced speed and correct seed size, can result in greatly improved planter performance.

8. CONCLUSIONS:

Population and Row Spacing.

The key to maximum sunflower yields is a plant population high enough to take full advantage of soil moisture, fertilizer and light. However, excessive plant numbers can put extra stress upon individual plants and reduce yields. For the Darling Downs, the following recommendations can be made:

* under weedfree conditions, row spacing for both irrigated and rainfed crops should be no wider than 36 cm.

* the optimum established plant population is 50 000 plants/ha for dryland crops, and 100 000 plants/ha for irrigated crops.

Crop Performance

Farmers must assess their sunflower crops on overall crop performance, rather than individual plant performance. This is due to the compensatory effect between population and head size and a lot of small heads will yield as much as fewer big heads. Smaller heads are more desirable, as harvesting problems can be experienced with very large heads.

Seed Distribution and Planter Performance

Research on seed distribution in sunflowers shows that uniform planting is necessary to obtain the best yields. Many farmers, however, have shown a reluctance to switch from a combine to other planters. They are dissatisfied with the precision obtained from present precision row crop planters to warrant the purchase and additional tooling up. Row crop planters have been largely unsuccessful as a result of an inability to consistently match planting seed with the proper plate.

Sunflower seed is difficult to grade to uniform size as it requires sizing by weight, width, thickness and length. Length in particular is difficult. Consequently, it may be insufficient to have one set of plates to plant all sunflower seed even if it is of one grade. Seed variation exists between batches, variety and from season to season.

Pneumatic precision planters do enable accurate planting of sunflowers. They are more expensive, but they do space seed uniformly in the row. They operate on a suction principle with seeds being held individually against a perforated disc which rotates and releases the seed directly into the furrow. The mechanism is gentle on the seed and seed bounce is minimal.

Greater uniformity in plant spacing is desirable. This can be achieved through better grading standards being used by seed companies together with an improvement in farmer use of conventional planting machinery. Alternatively, farmers can purchase a pneumatic precision planter. While this is an expensive initial outlay, it could be expected to pay for itself in the form of increased returns. However, farmer experience shows that such yield increases are between 15 and 20%, not 50% as cited by some machinery companies.

Conventional combines can be used to plant sunflowers successfully. However, it requires additional care at planting. The planting speed should be reduced to 8 km/hr to reduce tyne movement and seed scatter. Any seed meter will give more accurate results if vibrations, shocks and jolts are reduced.

Further improvement can be achieved by replacing convoluted rubber hoses with clear smooth plastic tubes. The smallest diameter which will allow seeds to pass without choking should be used. This will improve distribution accuracy of the tube by minimizing seed bounce in the tube.

9. ACKNOWLEDGEMENTS:

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C. Berg, Jondaryan.

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APPENDIX I

PLANT POPULATION ADJUSTMENT FACTOR LIST

a. STORED SOIL MOISTURE

Very wet	+ 10%
Wet	+ 5%
Average	0
Somewhat drier than average	- 5%
Definitely drier than average	- 10%
Extremely dry	- 15%

b. SOIL TYPE

Heavy clay or high organic	+ 5%
Loam	0
Sandy loam	- 5%
Sandy	- 10%
Very sandy or gravel near surface	- 15%

c. SUMMER TEMPERATURE (Compensate for evaporation rate).

North of U.S. Highway 2	+ 5%
Between U.S. Highway 2 and 1-94	0
South of 1-94, north of U.S. Highway 12	- 5%
South of U.S. Highway 12	+ 10%

d. FERTILITY LEVEL

Very high	+ 10%
Good	+ 5%
Average	0
Low	- 5%
Very Poor	- 10%

(Some fertilizer is always recommended when fertility levels are very low).

APPENDIX 2

PLANT POPULATION COMPUTATION TABLE (PLANTS/HA)

Adjustment % Total	Rainfall April - September (mm)		
	Zone A 450 - 500	Zone B 400 - 450	Zone C 350 - 400
+ 30	79 440	74 880	65 520
+ 25	81 000	72 000	63 000
+ 20	77 750	69 120	60 480
+ 15	74 520	66 240	57 960
+ 10	71 280	63 360	55 440
+ 5	68 040	60 480	52 920
0	64 800	57 600	50 400
- 5	61 560	54 720	47 880
- 10	58 320	51 840	45 360
- 15	55 080	48 960	42 840
- 20	51 840	46 080	40 320
- 25	48 600	43 200	37 800
- 30	45 360	40 320	35 280
- 35	42 120	37 440	32 760
- 40	38 880	34 560	30 240

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