CHAPTER 3

EFFECT OF PLANT POPULATION ON SEED YIELD AND QUALITY

INTRODUCTION

Hullability is related to seed size. Merrien *et al.* (1992), Roath *et al.* (1985) and Shamanthaka Sastry (1992) all found that the hullability of larger seed is better than for smaller seed. Dedio & Dorrell (1989) even declared that seed size is the most important factor determining hullability. The production of fine material is also related to seed size, with larger seed producing less fines (Chapter 2). It can therefore be inferred that the processing of larger seeds can be expected to be more efficient than the processing of smaller seed.

Without exception, seed size has been found to decrease with increasing plant population (Blamey, Zollinger & Schneiter, 1997; Esendal & Kandemir, 1996; Gubbels & Dedio, 1986; Loubser, Grimbeek, Robertson, Bronkhorst, Serfontein & van der Sandt, 1986; Miller & Fick, 1978; Ortegón & Díaz, 1997; Robinson *et al.,* 1980; Thompson & Fenton, 1979; Vannozzi, Giannini & Benvenuti, 1985; Villalobos *et al.*, 1994).

As seed size is also related to hullability and the production of fine material, hullability and oil cake quality may be indirectly affected by the plant population. The possibility also exists that these characteristics can be positively influenced by altering the plant population. However, planting less seed than the conventionally recommended rate to enhance the processing quality, should not impact negatively on yield and chemical composition of the seed.

The objectives of this experiment were to determine the effect of plant population on the hullability, seed composition, amount of fines produced, the potentially recoverable oil, the oil cake yield and the potential oil cake protein and crude fibre content of three South African sunflower cultivars.

MATERIALS AND METHODS

The field trial was planted on the 20th November 1997 at the ARC-Grain Crops Institute, Potchefstroom. A randomised complete-block design with two replicates was used with the factors cultivars (HV 3037, PAN 7392 and SNK 37) and plant population (20 000, 35 000 and 50 000 plants ha^{-1}) in a factorial arrangement. Plots consisted of four rows of 15 m length spaced 0.9 m apart. Plots were planted and thinned shortly after emergence to the desired populations (20 000, 35 000 or 50 000 plants ha^{-1}). Amounts of 69 kg N, 8 kg P, 4 kg K and 5 kg B ha^{-1} were applied at planting. Weeds were controlled with alachlor at 4 l ha^{-1}. An irrigation of 10 mm was applied shortly after planting. At 72 days after planting an irrigation of 30 mm was applied to relieve severe water stress. For the rest of the season dryland conditions prevailed.

For yield determination, 13 m of the two centre rows in each plot were harvested and threshed. The moisture content, hectolitre mass, thousand seed mass, hull content and hullability were determined as described in the materials and methods of Chapter 2 section II. Samples of the seed, kernels and kernel rich fraction were analysed for moisture, oil and protein contents by the PPECB Quality Assurance Laboratory (P.O. Box 433, Silverton 0127). Analysis of variance was done to determine the effects of cultivar and plant population on the seed yield, hectolitre mass, thousand seed mass, hull content, hullability, fine material and the chemical composition of the seed, kernels and the kernel rich fraction. The statistical analyses were executed using Statgraphics (Version 5, Statistical Graphics Corporation, Rockville, Maryland USA).

RESULTS

Table 8 summarises the significance of the F-values from the analyses of variance, and Table 9 the grain yield, hectolitre mass, thousand seed mass, hull content, hullability and the amount of fines, respectively. Grain yield was affected by both cultivar and plant population. SNK 37 yielded 19% less than the other cultivars. The yield of the 20 000 population was 15% higher than the yield of the 35 000 and 50 000 plants per hectare populations.

Table 8 Significance of the F values of the analyses of variance of the measured seed traits as influenced by the plant population and cultivar

Factor	DF	Grain yield	Hectolitre mass	Thousand seed mass	Hull content	Hull-ability	Fine material
Population	2	**	**	**	**	**	**
Cultivar	2	**	**	**	**	**	**
P × C†	4	NS	*	NS	NS	**	NS
Total	17						
CV (%)		8	2	10	4	15	24

**,* Significant at the 0.05 and 0.01 probability levels, respectively.

† Plant population × cultivar interaction.

The hectolitre mass was affected by a population × cultivar interaction. The hectolitre mass of PAN 7392 was only slightly influenced by plant population, with a mean value of 42.9 kg hl^{-1} (Table 9). For HV 3037 and SNK 37 however, the hectolitre mass increased 5.6 and 7.4% respectively, with an increase in plant population from 20 000 to 50 000 ha^{-1}. This increase in hectolitre mass with increased population is in agreement with the results of Gubbles & Dedio (1986).

Thousand seed mass was affected by both plant population and cultivar. HV 3037 had the highest thousand seed mass amongst the cultivars, and the thousand seed mass declined as the population increased, which agrees with previous findings (Blamey *et al.*, 1997; Esendal & Kandemir, 1996; Gubbels & Dedio, 1986; Loubser *et al.*,1986; Miller & Fick, 1978; Ortegón & Díaz, 1997; Robinson *et al.*, 1980; Thompson & Fenton, 1979; Vannozzi *et al.*, 1985; Villalobos *et al.*, 1994). Both plant population and cultivars affected the hull content. PAN 7392 had the highest and HV 3037 the lowest hull content. The hull content at the 20 000 population was slightly higher than at the other populations (Table 9). A population × cultivar interaction affected hullability. The hullability of HV 3037 declined almost linearly with 12 and 13 percentage points respectively from the 20 000 to the 35 000 and from the 35 000 to the 50 000 populations.

Table 9 The effect of plant population on the grain yield, hectolitre mass, thousand seed mass, hull content, hullability and production of fine material of three sunflower cultivars

Cultivar	Population (plants ha^{-1})			
	20 000	35 000	50 000	Mean
	Grain yield (kg ha^{-1})			
HV 3037	2555	2469	2752	2649a*
PAN 7392	2861	2465	2271	2533a
SNK 37	2391	1912	2025	2109b
Mean	2660a*	2282b	2349b	
	Hectolitre mass (kg)			
HV 3037	46.4	47.0	49.0	47.5a
PAN 7392	42.6	43.3	42.9	42.9c
SNK 37	45.6	46.1	49.0	46.3b
Mean	44.9b	45.5b	46.4a	
	Thousand seed mass (g)			
HV 3037	90.1	71.7	57.2	73.0a
PAN 7392	73.2	57.9	52.1	61.0b
SNK 37	74.0	51.6	48.6	58.0b
Mean	79.1a	60.4b	52.6c	
	Hull content (%)			
HV 3037	22.1	21.9	21.6	21.9c
PAN 7392	24.1	24.0	23.3	23.8a
SNK 37	23.6	22.2	22.3	22.7b
Mean	23.3a	22.7b	22.4b	
	Hullability (%)			
HV 3037	69.1	56.9	43.6	56.5b
PAN 7392	81.6	87.9	84.4	84.6a
SNK 37	71.3	50.5	52.1	58.0b
Mean	74.0a	65.1b	60.0b	
	Fine material (%)			
HV 3037	5.6	5.3	5.0	5.3c
PAN 7392	7.7	11.2	7.9	8.9a
SNK 37	6.1	7.7	7.5	7.1b
Mean	6.5b	8.1a	6.7b	

* Means of a parameter within a row or column followed by different letters are significantly different at $P \leq 0.05$.

The hullability of SNK 37 declined with almost 21 percentage points from the 20 000 population to the 35 000 population and remained unchanged for the 50 000 population. Plant population had little effect on the hullability of PAN 7392 (Table 9). The percentage fines produced was affected by both population and cultivar. PAN 7392 produced 3.6 percentage points more fines than HV 3037. Fines also increased with increased population (Table 9).

The significance levels obtained in the analyses of variance and the mean values for the moisture free oil, protein and crude fibre content of both the seed and kernels, the moisture and oil free yield, protein and crude fibre content of the kernel rich fraction and the potentially recoverable oil, are shown in Tables 10 and 11 respectively. According to the F-test the oil and protein content of seeds and kernels were not affected by plant population but were significantly affected by cultivars. The seed oil content of SNK 37 was approximately 3.5 percentage points higher than that of the other two cultivars, and the seed protein content of HV 3037 was 2.2 percentage points higher than that of the other two cultivars.

Small differences in kernel oil content were observed among cultivars. The kernel protein content of SNK 37 was 11% lower than the protein content of the other two cultivars. Seed crude fibre content was not affected by plant population but by cultivars. The crude fibre content of PAN 7392 seed was 16% higher than the mean of the other two cultivars which corresponds with its higher hull content.

The yield of the kernel rich fraction, which is a reflection of the oil cake, was affected by cultivar but not by plant population. The yield of the kernel rich fraction of HV 3037 was 16% higher than the mean yield of the other two cultivars. Plant population had no effect on the potential oil yield despite the higher production of fines from the 50 000 population and the accompanying loss of oil. The potentially recoverable oil however, was influenced by cultivars. Seed of HV 3037 and PAN 7392 did not differ in oil content but the potentially recoverable oil of HV 3037 was higher than that of PAN 7392. This might be due to the high production of fine material by PAN 7392. The potentially recoverable oil from the seed was 91, 83 and 88% for HV 3037, PAN 7392 and SNK 37 respectively.

Table 10 Significance of the F values of the analyses of variance of the moisture free oil, protein and crude fibre (CF) content of the seed and kernels, the protein and crude fibre content and yield of the kernel rich fraction and the potentially recoverable oil (PRO) as influenced by plant population and cultivar

Factor	DF	----------- Seed ----------			--------- Kernel --------			-- Kernel rich fraction --			PRO
		Oil	Protein	CF	Oil	Protein	CF	Yield	Protein	CF	
Population	2	NS	NS	NS	NS	NS	NS	NS	**	NS	NS
Cultivar	2	**	*	**	*	**	NS	**	**	NS	**
P × C[†]	4	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Total	17										
CV (%)		4	6	6	3	5	11	8	3	8	1

**,* Significant at the 0.05 and 0.01 probability levels, respectively.

[†] Plant population × cultivar interaction.

DISCUSSION AND CONCLUSIONS

The higher grain yield obtained at the 20 000 population as opposed to the other populations, is in contrast with the results of Loubser *et al*. (1986) who found that 20 000 plants ha^{-1} yielded significantly less than 40 000 or 60 000 plant ha^{-1} under high potential conditions. Intense water stress that developed during the first 7 days of the grain filling stage, most likely affected the yield. From the results of Sadras & Hall (1988) it is clear that 20 000 plant ha^{-1} will have a smaller leaf area index than 35 000 or 50 000 plant ha^{-1}. A slower rate of depletion of the soil water could be expected from the 20 000 population due to a smaller transpiring area. Water stress may therefore have been less severe in the 20 000 than in the higher plant populations.

The significantly higher hull content and hullability of grain from the 20 000 population also indicates a lower degree of water stress at this population density. According to Villalobos *et al.* (1996) growth of the hull is completed within two weeks after anthesis. The stage of hull development in our experiment coincided with the stress period. Baldini & Vannozzi (1996) and Merrien *et al*. (1992) found that seed produced on plots which received irrigation frequently,

Table 11 The mean moisture free oil, protein and crude fibre (CF) content of the seed and kernels, the moisture and oil free yield, protein and crude fibre content of the kernel rich fraction and the potentially recoverable oil (PRO) of three cultivars at three plant populations

Factor	----------- Seed -----------			----------- Kernel -----------			-–— Kernel rich fraction -----			PRO
	Oil (%)	Protein (%)	CF (%)	Oil (%)	Protein (%)	CF (%)	Yield (%)	Protein (%)	CF (%)	(g per 100 g seed)
Plant density ha^{-1}										
20 000	48.0a*	21.9a	16.1a	60.3a	27.0a	2.7a	34.9a	53.8a	18.8a	42.0a
35 000	49.2a	21.1a	16.0a	61.6a	25.3b	2.6a	34.5a	51.3b	20.6a	42.6a
50 000	48.6a	21.6a	15.1a	60.8a	26.3ab	2.7a	37.0a	50.6b	20.6a	43.0a
Cultivar										
HV 3037	48.2b	22.9a	15.5b	59.3b	27.8a	2.7a	39.0a	52.8a	19.5a	43.9a
PAN 7392	46.7b	21.1b	17.3a	60.8ab	26.4a	2.7a	32.0b	53.2a	19.7a	38.8b
SNK 37	50.9a	20.4b	14.4b	62.6a	24.4b	2.7a	35.3b	49.6b	20.8a	44.8a

* Means within a column for plant population or cultivar, followed by different letters are significantly different at $P \leq 0.05$.

hulled easier than seed produced on plots less often irrigated.

Plant density did affect seed size and hullability for two of the three cultivars. The results of the two cultivars agrees with to the results of Dedio & Dorrell (1989), Merrien *et al*., (1992), Roath *et al*., (1985) and Shamanthaka Sastry (1992) that thousand seed mass had no significant relationship with hullability (r = 0.14, NS). Denis & Vear (1996), however, found that the thousand seed mass of 36 hybrids produced at one locality correlated well with hullability, while no significant relationship existed for a second locality. It was shown in Chapter 2 that certain size classes of one cultivar did not differ in hullability, while for other cultivars size classes differed significantly in hullability. It seems that the seed size: hullability relationship is not universal.

Due to the differences in hullability among cultivars and plant densities, differences in the crude fibre content of the kernel rich fractions were expected. However, the crude fibre analyses of the kernel rich fractions did not show significant differences, which can not be logically explained. A lack of accuracy of the chemical analyses might be the cause. The implication of these results is that for dryland sunflower production the plant population should rather be closer to 20 000 plants ha^{-1} than to 40 000 plants ha^{-1}. This will maximise hullability and minimise losses due to fine material, without affecting the oil and protein content of the seed.

The work reported in this chapter has been published (Nel, Loubser & Hammes, 2000a).