CHAPTER 7

EFFECT OF WATER STRESS DURING GRAIN FILLING ON SEED YIELD AND QUALITY

INTRODUCTION

The yield of sunflower is profoundly affected by water stress (Muriel & Downes, 1974; Talha & Osman, 1975). Seed composition is also affected by water stress. Water stress during the vegetative and reproductive growth stages reduces the seed oil content (Muriel & Downes, 1974; Hall *et al.*, 1985). Seed protein content, however, seems to be less affected by water stress after anthesis than the oil content (Connor & Sadras, 1992).

Water stress during seed filling affect physical seed characteristics like the seed size (Baldini & Vannozzi, 1999), hectolitre mass (Unger, 1982) and hull content (Connor & Hall, 1997). The effect of water stress on seed hullability, a seed trait determining the efficiency of seed processing and the quality of the oil cake, is still unknown. Denis, Dominguez & Vear (1994) grew several genotypes at two localities and found the hullability of seed from the drier locality to be higher than seed from the wetter locality. Merrien *et al.* (1992) and Baldini & Vannozzi (1996) on the other hand, found the hullability of seed from a frequently irrigated treatment to be higher than that of a less frequently irrigated treatment.

As water stress affects yield and seed composition, the objective of this field trial was to create two levels of crop water stress during the reproductive period, to quantify it and measure its effect on the seed yield, some physical and chemical seed characteristics, hullability and the potentially recoverable oil and the oil cake yields of three cultivars.

MATERIALS AND METHODS

A field trial, designed with three complete blocks was planted on 20th November 1997 at ARC-Grain Crops Institute, Potchefstroom. Plots consisted of four rows spaced at 0.9 m and 10 m long. After emergence seedlings were thinned to 35 000 plants ha^{-1}. Treatments consisted of three genetically unrelated cultivars (HV 3037, PAN 7392 and SNK 37) and crop water stress (high and low water stress). The low water stress treatment received 55 mm of irrigation at the opening of the inflorescence on 26th January 1998, which is growth stage R4 according to Schneiter & Miller (1981), and another 55 mm two weeks later. The high water stress treatment received no irrigation. From planting to growth stage R4, 166 mm of rain was recorded. On days 15, 20 23 and 24, after R4, 0.5, 1.8, 9.7 and 6.7 mm of rain was recorded. On day 25 after R4, 93 mm of rain was recorded which terminated the stress treatment.

To quantify the crop water stress, the relative water content of the leaves was measured twice a week from growth stage R4 to R8. This was done by clipping approximately 4 cm^2 from the tip of one of the five upper leaves from four randomly chosen plants from the two inner rows of each plot between 12:00 and 13:00. The leaf cuttings were immediately sealed in a plastic bag to prevent water loss, transported to a laboratory and the fresh mass determined. After floating the cuttings on de-ionised water in closed petri-dishes for 18 h at room temperature in darkness, the turgid mass was determined. The dry mass was measured after drying for 3 h at 75°C. The relative water content (RWC) was calculated as follows:

$$RWC = ((\text{Fresh mass - dry mass})/(\text{Turgid mass - dry mass})) \times 100\%$$

Grain yield was measured by harvesting 8 m each from the two central rows per plot. The hectolitre mass, moisture content, thousand seed mass, hull content and hullability were measured as previously described in the materials and methods of Chapter 2 section II. After dehulling, samples of the seed, kernels and kernel rich fractions were chemically analysed for oil, protein, crude fibre and moisture content (PPECB Quality Assurance Laboratory, P.O. Box 433, Silverton, 0127).

The potentially recoverable oil, the oil and moisture-free yield of the KRF, and the protein and crude fibre content of the KRF were calculated as described in the materials and methods of Chapter 2 section II. Analyses of variance were done on the data collected using Statgraphics (Version 5, Statistical Graphics Corporation, Rockville, Maryland USA).

RESULTS AND DISCUSSION

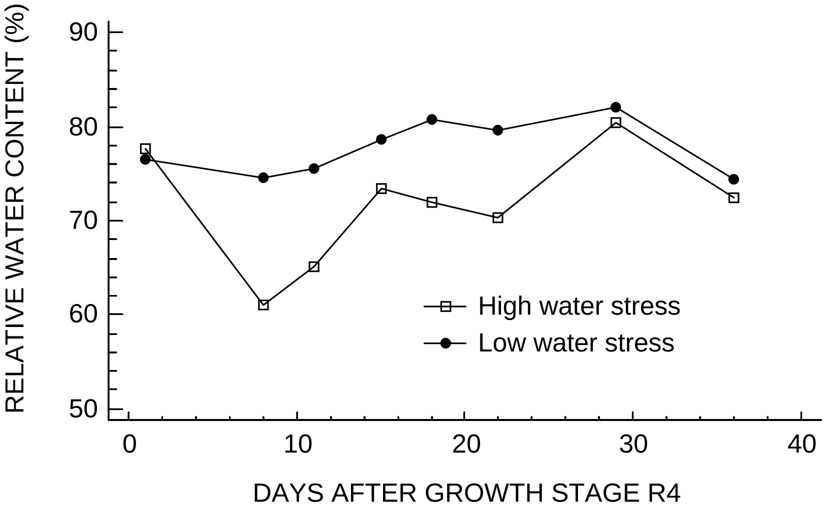
Crop water stress

Due to the irrigation applied to the low water stress plots, the RWC of the low and high water stress treatment levels differed from the R4 stage until 25 days later when 93 mm of rain alleviated it (Figure 5). The occurrence of less rain than 10 mm day^{-1} had no measurable effect on the RWC nor were differences among cultivars measured at any stage. According to norms laid down by Hsiao (1973), the difference in water stress between the two treatment levels varied from moderate at 8 and 11 days after R4, to mild at 15, 18 and 22 days after R4. Calculated for the period of measurement which covered the whole grain filling period, the RWC of the low and high stress levels was 77.8 and 71.4% respectively. The high stress level therefore experienced a mild stress compared to the low stress treatment (Hsiao, 1973) for the duration of the reproductive growth period.

Yield and physical seed characteristics

Grain yield was affected by crop water stress with the high stress level yielding 23% less than the low stress level (Table 30). The thousand seed mass was affected by both cultivar and crop water stress. Calculated over cultivars the thousand seed mass for the high stress level was 18% lower than that for the low stress level. The reduction in grain yield was thus mainly due to the reduction in thousand seed mass.

The hectolitre mass was affected by crop water stress, cultivars and an interaction between the two factors (Table 30). Both HV 3037 and PAN 7392 had higher hectolitre mass values for the high crop water stress level than for the low stress level while SNK 37 was unaffected (Table 31). Differences in hectolitre mass amongst cultivars were larger than between the high and low crop water stress levels with PAN 7392 having only 90% of the hectolitre mass of HV 3037.



Hull content was affected by cultivar and crop water stress × cultivar interaction (Table 30). The hull content of PAN 7392 and SNK 37 for the low crop water stress level was approximately 3% higher than for the high stress level (Table 31). The opposite was found for HV 3037 where the hull content of the low crop water stress level was approximately 8% lower than of the high stress level, The change in hull content was small in comparison to the changes in yield and the thousand seed mass, brought about by the water stress levels.

Hullability was affected by both crop water stress and cultivar (Table 30). Hullability for the high crop water stress level was 14% lower than for the low stress level. This supports the observations of Baldini & Vannozzi (1996) and Merrien *et al* (1992) that seed from frequently irrigated plots hulled easier than seed from less frequently irrigated plots. Differences in hullability amongst cultivars were larger than between the high and low crop water stress levels with HV 3037 having only 60% of the hullability of PAN 7392.

Table 30 Grain yield, hectolitre mass, thousand seed mass (TSM), hull content, hullability and fines produced during dehulling from the seed of three sunflower cultivars as affected by crop water stress during the grain filling period.

Treatment	Grain yield (kg ha $^{-1}$)	Hectolitre mass (kg hl $^{-1}$)	TSM (g)	Hull content (%)	Hullability (%)	Fines (%)
Crop water stress						
Low	2814a[‡]	46.4b	61.4a	22.1a	66.9a	8.9a
High	2170b	47.6a	50.6b	22.2a	57.5b	8.3a
Cultivar						
HV 3037	2570a	49.4a	56.6b	20.8c	46.3c	7.0b
PAN 7392	2483a	44.7c	49.4c	23.8a	80.2a	11.1a
SNK 37	2422a	47.0b	62.0a	21.9b	60.0b	7.7b
Significance of the F values from the analysis of variance						
Water stress	**	**	**	NS	**	NS
Cultivar	NS	**	**	**	**	**
W × C[†]	NS	*	NS	**	NS	**
CV(%)	11	3	9	3	10	14

[‡] Means followed by different letters in a column differ significantly at $P \leq 0/05$.

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

[†] W × C = water stress × cultivar interaction.

Table 31 Interactions of hectolitre mass, hull content and fines produced of three cultivars at the low and high water stress levels

Cultivar	Hectolitre mass (kg hl $^{-1}$)		Hull content (%)		Fines (%)	
	Low stress	High stress	Low stress	High stress	Low stress	High stress
HV 3037	48.7	50.0	19.9	21.6	6.5	7.4
PAN 7392	43.5	45.9	24.1	23.5	11.5	10.6
SNK 37	47.0	47.0	22.2	21.5	8.7	6.8

Table 32 The moisture free protein, oil and crude fible (CF) content of the seed and kernels, the potentially recoverable oil (PRO) and the oil and moisture free protein and crude fibre content and yield of the kernel rich fraction (KRF) of three cultivars as affected by crop water status during the grain filling period

Factor	--------------------Seed--------------------			------------------Kernel------------------			PRO	--------------------KRF--------------------		
	Protein	Oil	CF	Potein	Oil	CF		Yield	Protein	CF
	(%)	(%)	(%)	(%)	(%)	(%)	-----g 100 g seed-----		(%)	(%)
Water stress										
Low	18.2a[‡]	50.3a	18.2a	22.0a	64.4a	2.9a	43.5a	32.7a	47.1a	24.2a
High	19.6a	49.6a	17.9a	23.1a	62.9b	2.9a	44.1a	34.5a	49.1a	23.8a
Cultivar										
HV 3037	19.8a	50.7b	16.5b	23.7a	62.4b	3.0a	45.8a	36.9a	48.6a	24.1a
PAN 7392	19.0ab	46.9c	20.5a	23.1a	63.2b	2.7a	38.9b	30.3c	50.1a	23.2a
SNK 37	17.8b	52.2a	17.1b	20.8b	65.2a	3.0a	46.8a	33.6b	45.6b	24.7a
Significance of the F values from the analysis of variance										
Water stress	NS	NS	NS	NS	*	NS	NS	NS	NS	NS
Cultivar	NS	**	**	*	**	NS	**	**	*	NS
W × C[†]	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	7	2	6	6	2	9	3	5	4	9

[‡] Means followed by different letters in a column differ significantly at at P ≤ 0/05.

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

[†] W × C = water stress × cultivar interaction.

The production of fine material which is an indication of losses during processing was affected by cultivar and crop water stress × cultivar interaction (Table 30). The fine material produced by PAN 7392 and SNK 37 showed a decline of 8 and 22% respectively, from the low to the high crop water stress level. HV 3037 on the other hand showed an increase of approximately 14% in the production of fine material from the low to the high crop water stress level (Table 31).

Chemical composition and potentially recoverable oil and yield of the kernel rich fraction

The protein, oil and crude fibre content of the seed, the kernel and the kernel rich fraction, the potentially recoverable oil and the oil and moisture free yield of the kernel rich fraction, are shown in Table 32. Seed oil content was not affected by the crop water stress treatment but by cultivar only. This seems to contradict the results of Alessi *et al* (1977), Hall *et al* (1985), Muriel & Downes (1974) and Talha & Osman (1975). However, the moisture free oil content of the kernels was affected by the crop water stress treatment with the high stress level containing 2.3% less oil than the low water stress level. The wild water stress thus reduced the oil content of the kernels which was most likely obscured from the seed analyses due to the presence of the hulls. The protein and crude fibre content of the seed were not affected by the water stress treatments. Seed oil and crude fibre content differed amongst cultivars.

The moisture and oil free yield and protein content of the kernel rich fraction, which is an indication of the yield and quality of the oil cake that can be expected, was not affected by the water stress treatments. It was, however, affected by the cultivar (Table 32). The crude fibre content of the kernel rich fraction was not affected by the water status treatment nor by cultivar, which is unexpected considered the differences in hullability observed. This might be due to variation in the crude fibre content of the hulls which was not determined in this investigation. Theerta Prasad & Channakrishnaiah (1995) reported the fibre content of hulls to vary from 59 to 87%. Smith *et al* (1989) also found the crude fibre content of South African produced seed to vary from 13 to 28%, much more than the oil or protein content.

CONCLUSIONS

A mild water stress developed and persisted for the first 25 days of the reproductive growth period for the high water stress level, compared to the low water stress level. Grain yield, which was reduced by 23%, was more sensitive to this water stress than any of the physical or chemical seed traits. Hullability was reduced by 14% and the kernel oil content by only 2.3% while the seed composition was not affected. The potentially recoverable oil was not affected by the water stress nor were the yield of the kernel rich fraction or its protein and crude fibre contents. How the seed quality parameters will be affected by moderate or severe water stress and stress during the latter part of the reproductive stages is still unknown. Due to the difference in seed composition, hullability and production of fine material of cultivars, the potentially recoverable oil, yield of the kernel rich fraction and protein content differed amongst cultivars.

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