CHAPTER 5

EFFECT OF NITROGEN FERTILISATION ON SEED YIELD AND QUALITY

INTRODUCTION

The availability of nitrogen throughout the growing season is one environmental factor which varies considerably among commercial sunflower fields due to various fertilisation rates, different soils and variation in rainfall. Previous research has indicated that under nitrogen limiting conditions, nitrogen fertilisation tends to increase seed protein content at the expense of oil (Blamey & Chapman, 1981; Loubser & Grimbeek, 1985; Steer *et al.*, 1986). Even in conditions where seed yield was not affected by nitrogen fertilisation, higher levels of nitrogen reduced seed oil content (Geleta, Baltensperger, Binford & Miller, 1997).

In a greenhouse trial, Steer *et al.* (1984) found that timing of nitrogen fertilisation during the growing season influenced seed oil and protein contents. High nitrogen supply after anthesis resulted in lower seed oil and higher protein contents. Hullability is also affected by the availability of nitrogen and water. In this respect Baldini & Vannozzi (1996) have found that an increased supply of nitrogen improves hullability.

It appears that the availability of nitrogen to the sunflower crop may have a determining effect on seed characteristics which influence the processing quality. The objectives of this field trial were to determine the effect of both the amount and timing of nitrogen fertilisation on the seed yield, hullability, seed composition, potential oil yield, potential oil cake yield and potential quality of the oil cake.

MATERIALS AND METHODS

The field experiment was located at the ARC-Grain Crops Institute's experimental farm at Potchefstroom. According to the Soil Classification Working Group (1991) the soil is classified as being of the Kameelbos family and the Avalon form, 60 cm deep with a sandy clay loam texture in both the A and B horizons. In an attempt to deplete the soil of residual nitrogen, oats were sown without fertilisation during June, mowed 100 days later and all the material removed. The experimental area was subsequently fertilised with 28 kg ha^{-1} P and 28 kg ha^{-1} K and ploughed. Seed of the cultivar HYSUN 333 was densely planted in rows spaced 90 cm apart on 14 December 1998 and thinned to approximately 35 000 plants ha^{-1} after emergence. HYSUN 333 was chosen for its hullability response to environmental influences (Chapter 4). For weed control, alachlor was applied at a rate of 4 l ha^{-1} after sowing.

A completely randomised block design was used with two treatment factors and three replicates. Plot dimensions were 10×3.6 m. Treatments consisted of nitrogen application rate and timing of application. The different N rates included inadequate (20 kg ha^{-1} N), adequate (70 kg ha^{-1} N) and luxurious (120 kg ha^{-1} N) supply. Timing of application treatments were: all N applied at planting (1:0) , 25% at planting and 75% at the beginning of flowering (1:3) and equal quantities at planting and at the beginning of flowering (1:1), which is growth stage R5.1 as described by Schneiter & Miller (1981).

Before the first nitrogen application, six topsoil samples were taken on each plot to a depth of 60 cm, mixed to one sample and analysed for NO^-_3 and NH^+_4 nitrogen content. NH^+_4 ranged between 5.2 and 9.0 mg kg^{-1}, and NO^-_3 between 3.2 and 8.3 mg kg^{-1}, with means of 6.8 and 5.9 mg kg^{-1} respectively.

To supplement low rainfall, irrigation was applied several times during the season. Leaf samples were taken at growth stage R4 before the second application of nitrogen and analysed for total nitrogen content. The seed yield was determined on an area of 1.8×8 m for each plot. The hectolitre mass, thousand seed weight and hull content were determined as described in the materials and methods section of Chapter 2, section II.

The seed was dehulled and separated into the three fractions as described in the materials and methods section of Chapter 2 section II. Due to the low moisture content of the seed (5.7%), the huller speed was set at 3800 rpm and three samples of approximately 15 g seed were used. The mass of each of the three fractions was recorded. Hullability was calculated as described previously (Chapter 2). Samples of the seed, clean kernels and kernel-rich fractions were chemically analysed for moisture, oil and protein content (N × 6.25%) by the PPECB Quality Assurance Laboratory (PO Box 433, Silverton 0127).

RESULTS AND DISCUSSION

Leaf nitrogen content at growth stage R4 responded to the amount of nitrogen applied at planting (Table 21). Cheng & Zubriski (1978) found a nitrogen concentration of 2.79 % in the leaves to be associated with a yield reduction of approximately 10%. Only the 20 kg ha^{-1} and 1:1 timing treatment combination, which received only 10 kg nitrogen per ha at planting, was deficient at 2.71 %. The nitrogen concentration for all other treatment combinations indicated adequate nitrogen supply. The absence of a clear deficit for the 20 kg nitrogen treatment is explained by the high soil nitrogen content. Approximately 46 kg residual nitrogen, bound as NO_3^-, was available per ha, which, according to Robinson (1973), is adequate to produce 1000 kg seed per ha.

Table 21 Leaf nitrogen content (%) at growth stage R4 in response to the N applied at planting

N timing ratio	------------Total N application rate (kg ha^{-1})-------------		
(Planting:R5.1)	20	70	120
1:3	2.88 (5)†	3.01 (17.5)	3.07 (30)
1:1	2.71 (10)	3.11 (35)	3.35 (60)
1:0	2.88 (20)	3.31 (70)	3.86 (120)

† Amount of nitrogen (kg ha^{-1}) applied at planting.

The grain yield increased by 33% with increasing nitrogen application from 20 to 70 kg ha^{-1}, while it increased by only 9.6% in response to an increase from 70 to 120 kg nitrogen per ha (Tables 22 and 23). The mean grain yield achieved, viz. 2642 kg ha^{-1}, represents yields commonly obtained for irrigated rather than dryland sunflower production in South Africa. Despite no indication of a serious deficiency it appears as though 120 kg nitrogen per ha was not sufficient to produce maximum seed yields for the conditions that prevailed.

The hectolitre mass was affected by the amount of nitrogen applied. However, the response was small with an increase of only 2% for each increment of 50 kg of nitrogen applied (Table 3). Neither the amount of nitrogen applied nor the timing of application had any affect on the thousand seed weight (mean 61.2 g), hull content (mean 24.1%), hullability (mean 54.7%) or the amount of fine material produced (mean 6.3%).

The lack of a response of hullability to increased nitrogen fertilisation apparently does not support the findings of Baldidni & Vannozzi (1996) who have found hullability to be improved by nitrogen fertilisation. The apparent discrepancy might be explained by the different nitrogen application rates and conditions used in the two experiments. In the Potchefstroom trial, nitrogen application varied from 20 to 120 kg ha^{-1}, compared to the extreme rates of 0 and 180 kg nitrogen ha^{-1} combined with high and low water availability in the trial of Baldini & Vannozzi (1996). Recommended nitrogen fertilisation rates for dryland conditions with a yield potential of 2000 kg ha^{-1} in South Africa vary from 40 to 70 kg N ha^{-1}, depending on the clay content of the soil (du Toit, Loubser & Nel, 1995). Assuming that these recommendations also reflect the actual nitrogen applications by farmers, it seems unlikely that the hullability of commercially produced seed is affected by nitrogen fertilisation.

Seed oil content decreased while seed protein content increased with increased amounts of applied nitrogen (Tables 24 and 25) thereby supporting previous findings (Blamey & Chapman, 1981; Loubser & Grimbeek, 1985; Steer *et al.*, 1986). Timing of nitrogen application had no effect on the seed oil and protein content (Table 4). Steer *et al*. (1984), however, have found in a controlled environment with sunflowers grown in washed sand that high nitrogen supply compared with a low supply during seed filling gave a high seed nitrogen concentration.

Table 22 F-values from the analysis of variance for grain yield and physical seed characteristics of sunflower as affected by rate and timing of nitrogen application

Source of variation	DF	Grain yield	Hectolitre mass	Thousand seed weight	Hull content	Hull-ability	Fine material
N-amount	2	25.6**	5.9*	1.2	2.5	0.9	0.1
N-timing	2	0.9	0.6	1.6	1.8	0.2	0.2
Interaction	4	2.8	0.1	1.5	1.4	0.8	0.5
Total	26						
CV (%)		10	3	7	3	15	13

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

Table 23 Grain yield and physical seed characteristics of sunflower as affected by rate and timing of nitrogen application

Treatment	Grain yield (kg ha^{-1})	Hectolitre mass (kg hl^{-1})	Thousand seed weight (g)	Hull content (%)	Hull-ability (%)	Fine material (%)
N-amount (kg ha^{-1})						
20	2096	45.7	59.3	24.4	54.2	6.32
70	2800	46.6	61.7	23.8	55.8	6.16
120	3027	47.4	62.4	24.0	54.2	6.42
N-timing (Planting:R5.1)						
1:3	2548	46.3	61.8	23.6	52.7	6.34
1:1	2768	46.8	62.2	24.2	55.0	6.27
1:0	2608	46.5	59.5	24.2	56.5	6.3

Similar to seed oil and protein content, kernel oil content declined and protein content increased with increased rate of nitrogen fertilisation (Tables 24 and 25).

In commercially grown sunflower, kernel crude fibre content in excess of 10% is sometimes found, which is of concern since oil cake with unacceptably high crude fibre content can thus be expected. The kernel crude fibre content was significantly affected by the timing of nitrogen fertilisation at the 5.2% probability level. Increasing the portion of nitrogen applied at growth stage R5.1 resulted in a moderately increased kernel fibre content (Table 25). However, considering the levels and timing of nitrogen fertilisation on commercial fields it is unlikely that crude fibre levels in excess of 10% are the result of nitrogen supply.

The amount of potentially recoverable oil decreased moderately with less than two percentage points for each increment of 50 kg nitrogen applied per ha (Tables 24 and 25). The change in the potentially recoverable oil corresponds with the changes in both the seed oil and kernel oil contents due to the amount of nitrogen applied.

The oil and moisture-free yield of the KRF gives an indication of the oil cake yield that can be expected from the seed. The KRF yield was affected by the amount of nitrogen fertiliser applied (Table 24). Each increment of 50 kg of nitrogen per ha resulted in a small KRF yield increase of approximately 1.5 percentage points (Table 25). This increase in the KRF yield is explained by the higher protein and lower oil content of the seed associated with the higher rates of nitrogen fertilisation.

The oil and moisture-free protein and crude fibre contents of the KRF, which reflect the quality of the oil cake, were affected by the amount of nitrogen applied (Table 24). The protein content increased with 4.1 percentage points per 50 kg of nitrogen applied (Table 25). The crude fibre content decreased with 1 and 3.1 percentage points from the 20 to the 70 kg and from the 70 to the 120 kg nitrogen per ha respectively (Table 25). The change of the KRF composition was also due to the change in seed composition associated with different nitrogen application rates.

Table 24 F-values from the analysis of variance for seed and kernel composition, potentially recoverable oil (PRO) and the yield and composition of the kernel-rich fraction (KRF) of sunflower as affected by rate and timing of nitrogen application

Source of	DF	----------------Seed----------------			-------------Kernel-----------------			PRO	-----------------KRF----------------		
variation		Oil	Protein	Fibre	Oil	Protein	Fibre		Yield	Protein	Fibre
N-amount	2	11.1**	21.6**	0.5	24.1**	25.9**	0.7	11.5**	5.6*	14.8**	4.5*
N-timing	2	0.1	0.5	0.5	0.7	1	3.7	0.1	1.5	0.3	0.2
Interaction	4	0.7	0.1	2.2	0.4	0.2	0.7	0.6	0.3	0.3	0.3
Total	26										
CV (%)		4	9	6	3	8	9	3	5	7	10

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

Table 25 Seed and kernel composition, potentially recoverable oil (PRO) and the yield and composition of the kernel-rich fraction (KRF) of sunflower as affected by rate and timing of nitrogen application

Treatment	Seed†			Kernel†			PRO†	KRF‡		
	Oil	Protein	Fibre	Oil	Protein	Fibre		Yield	Protein	Fibre
	(%)	(%)	(%)	(%)	(%)	(%)	g per 100 g		(%)	(%)
N-amount (kg ha^{-1})										
20	50.2	15.4	19.7	65.4	19.7	4.9	45.6	34.8	40.5	31.7
70	49.3	17.9	19.3	62.5	22.8	4.8	44.5	36.4	44.6	30.7
120	46.6	20.3	19.8	59.8	25.8	5.1	42.8	37.8	48.7	27.6
N-timing (Planting:R5.1)										
1:3	48.6	18.3	19.7	62.1	23.4	5.3	44.5	37.2	45.1	30.3
1:1	48.7	17.6	19.3	62.5	22.6	4.9	44.3	36.2	44.0	29.5
1:0	48.8	17.8	19.8	63.1	22.3	4.7	44.2	35.7	44.6	30.3

† Moisture-free basis

‡ Oil and moisture-free basis

Smith *et al.* (1989) have found the mean oil and moisture contents of commercially produced oil cakes to be 6.68 and 6.73% respectively. Applying this to the KRF composition, the protein contents would be 35.1, 38.6 and 42.2% and the crude fibre content would be 27.4, 26.6 and 23.9% for the 20, 50 and 120 kg ha^{-1} nitrogen application rates respectively. Accordingly, only the 120 kg ha^{-1} nitrogen application rate would be expected to yield oil cake with an acceptable (above 40%) protein content. The crude fibre content, however, is more than double the value that can be considered as acceptable for sunflower oil cake of high quality (Smith *et al*., 1989).

CONCLUSION

Timing of nitrogen application had no response on the seed yield or the seed quality characteristics of sunflower. Seed yield increased on average by 22% per 50 kg of nitrogen applied per ha, while changes in the recoverable oil yield, KRF yield and composition of the KRF were equal to or less than 10%. These changes were due to changes in seed composition as the hullability was unaffected by nitrogen application rate. For commercial seed production it seems logical that seed yield would remain the main determinant for nitrogen application rates rather than the composition of the seed.

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