CHAPTER 6

EFFECT OF BORON FERTILISATION ON SEED YIELD AND QUALITY

INTRODUCTION

The importance of B deficiency for sunflower (*Helianthus annuus* L.) in South Africa has been reported by Blamey (1976) and Blamey & Chapman (1982). Yield increases of up to 30.7% (Armstrong & McGee, 1982) and 48% (Blamey, Mould & Chapman, 1979) have been reported as a result of fertilisation with B on deficient soils. Fertilisation with B at planting has become a standard procedure for many farmers. Despite these fertilisation practices, B deficiency symptoms are reported every year in South Africa. This is not surprising since B deficiency is unusual in that drought stress affects its incidence and severity, especially under low topsoil moisture conditions (Moraghan & Mascagni, 1991). According to Batey (1971) turnip (*Brassica rapa*) in Wales normally becomes B deficient on soils with less than 0.3 mg kg^{-1} of extractable B. However, deficiency in a dry summer was observed in fields with extractable B levels of 0.5 to 0.6 mg kg^{-1}. On the other hand, fertilisation with B sometimes suppresses seed yields. In field trials done by the Fertilizer Society of South Africa (FSSA, 1977), the lowering of sunflower seed yields or a declining trend in yield due to B-fertilisation, were observed. Hilton & Zubriski (1985) found in North Dakota that the yield of a B-fertilised treatment was the lowest at three out of four sites, and significantly lower than a treatment which was fertilised with Fe and S.

Apart from the effect of B on yield, seed oil content can also be affected by B supply (Blamey *et al.*, 1979; Chatterjee & Nautiyal, 2000). The effect of B supply on the other seed quality characteristics is not known. As some of the sunflower produced in South Africa may be affected by B availability, the objectives of this trial were to determine the effect of B fertilisation on the seed yield, the physical and chemical seed characteristics and the potentially recoverable oil, potential oil cake yield, and the protein and crude fibre contents of the potential oil cake.

MATERIALS AND METHODS

Two field trials were planted during the 1999/2000 season at two localities in the sunflower production area of South Africa, on fields where B deficiency was observed during previous seasons. The localities were the ARC-Small Grain Institute at Bethlehem and the farm "Hoekom" close to Petrus Steyn. Details of the soils at these two experimental sites and the agronomic practices applied are shown in Table 26.

Treatments applied were: soil surface applications of B at a rate of 1.6 kg ha^{-1} as sodium borate (Solubor); B at a rate of 1.6 kg ha^{-1} as sodium calcium borate (Boronat 32, supplied by Agrofert, P.O. Box 518, Ferndale 2120, South Africa); and a control treatment which received no B. Sodium calcium borate (SCB) is less soluble than sodium borate (SB) and thus expected to be less susceptible to leaching.

Completely randomised block designs were used, with three replicates at Bethlehem and five replicates at Petrus Steyn. Plots consisted of four rows, 0.9 m apart and 10 m long. The inner two rows were harvested for yield and seed quality determinations. At growth stage R5.1, as described by Schneiter & Miller (1981), the youngest fully expanded leaf blades were sampled. These samples were dried at 65°C and analysed for B content by the ARC-Institute for Soil Climate and Water (Private Bag X79, Pretoria 0001, South Africa).

The hectolitre mass of the seed, thousand seed mass and hull content were determined as described in the materials and methods of Chapter 2 section II. Seed dehulling, separation into the different fractions, calculation of hullability, fines produced and chemical analyses were done as described in the materials and methods of Chapter 5.

The potential oil yield, 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 Plus (Manugistics, Inc., 2115 East Jefferson Street, Rockville, Maryland 20852, USA).

RESULTS

Results of the B content of the leaves, the seed yield and physical seed characteristics are shown in Table 27. At both localities, the B content of the leaves was above the 34 mg kg^{-1} threshold for deficiency, as determined by Blamey *et al.* (1979) and Fernandez, Baudin, Esquinas & Vara (1985), and well below the toxicity limit of 1130 mg kg^{-1}, as determined by Blamey, Asher & Edwards (1997). Leaf B content did not differ amongst treatments at Bethlehem. At Petrus Steyn, however, the leaf B content in the Boronat treatment was 35% higher than in the control treatment.

Seed yield decreased by 12% at Bethlehem due to B fertilisation. At Petrus Steyn, the seed yield of the SB treatment was almost 25% higher than the yield of the control treatment. SB lowered the hectolitre mass of the seed by 3.8% compared to the control treatment at Bethlehem, while the hectolitre mass was unaffected at Petrus Steyn. The thousand seed mass, hull content and fine material were unaffected by the B fertilisation or the type of B fertiliser used at either locality. At Bethlehem the hullability of the SCB treatment was 16.6% lower than that of the control treatment. Hullability was unaffected by the B fertilisation at Petrus Steyn.

The oil, protein and crude fibre contents of both the seed and kernels were unaffected by the treatments at either locality (Table 28). The differences in the seed oil and protein contents between the two localities are remarkable, taking into account that the yields differ by only 3%. The seed produced at Bethlehem had an exceptionally high oil content (47.5% at 7% moisture content) associated with an exceptionally low protein content (12.6% at 7% moisture content). At Petrus Steyn, the seed oil content was very low at 37.3% (at 7% moisture) while the seed protein content can be described as normal at 21.1%.

Results of the potentially recoverable oil, KRF yield and the protein and crude fibre contents of the KRF, as affected by B fertilisation, are shown in Table 29. B fertilisation had no effect on the potentially recoverable oil of the seed.

Table 26 Soil description and agronomic inputs of the field trials at two localities

Soil parameters and inputs	--------------- Locality ---------------	
	Bethlehem	Petrus Steyn
Soil classification	Avalon	Avalon
Effective depth (m)	0.7	1
pH (KCl) 0 - 0.3 m depth	5.5	3.9
Ca (Ambic 1, mg kg^{-1})	639	148
K (Ambic 1, mg kg^{-1})	167	93
Mg (Ambic 1, mg kg^{-1})	139	30
P (Ambic 1, mg kg^{-1})	11	19
Planting date	1999-10-28	2000-01-6
Cultivar	HV 3037	HYSUN 333
Plant density (plants m^{-2})	4	1.2
N fertilisation (kg ha^{-1})	61	64
P fertilisation (kg ha^{-1})	13	17
K fertilisation (kg ha^{-1})	6	8

The moisture and oil-free yield of the KRF, which is an indication of the yield of the expected oil cake, was affected by the application of SCB at Bethlehem where its seed yield was 7.3% higher than that of the control treatment. This higher KRF yield is explained by the lower hullability of the SCB treatment, which resulted in more hulls remaining in the KRF. The lower hullability of the SCB treatment, compared to the control, is also the cause of the difference in the KRF protein content between these two treatments (Table 29). B fertilisation, however, had no effect on the KRF yield or protein content at Petrus Steyn.

The crude fibre content of the KRF was unaffected by the application of B at either locality. This is unexpected for the Bethlehem trial and cannot be logically explained. Approximate equal differences between the crude fibre content of the KRFs, and between the hullabilities of the SCB and control treatments, were expected.

Table 27 Leaf B content at growth stage R5.1, grain yield, hectolitre mass, thousand seed mass, hull content, hullability and the amount of fine material produced as affected by fertilisation with sodium borate (SB) and sodium calcium borate (SCB) at two localities

Treatment	Locality	
	Bethlehem	Petrus Steyn
	B content (mg kg^{-1})	
Control	54.5a*	74.2b
SB	57.8a	84.4ab
SCB	77.1a	100.0a
	Grain yield (kg ha^{-1})	
Control	2801a	2236b
SB	2437b	2792a
SCB	2493b	2462ab
	Hectolitre mass (kg hl^{-1})	
Control	39.3a	38.8a
SB	37.8b	39.9a
SCB	38.5ab	39.5a
	Thousand seed mass (g)	
Control	58.7a	75.4a
SB	54.7a	74.1a
SCB	47.9a	73.4a
	Hull content (%)	
Control	23.2a	29.7a
SB	24.0a	28.4a
SCB	22.5a	28.2a
	Hullability (%)	
Control	89.3a	88.2a
SB	85.2a	92.7a
SCB	74.5b	88.3a
	Fine material (%)	
Control	5.2a	4.8a
SB	5.5a	5.4a
SCB	5.5a	5.0a

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

Table 28 The oil, protein and crude fibre contents of the seed and kernels of sunflower as affected by fertilisation with sodium borate (SB) and sodium calcium borate (SCB) at two localities

Treatment	---------------------------------------Locality---------------------------------------					
	Bethlehem	Petrus Steyn	Bethlehem	Petrus Steyn	Bethlehem	Petrus Steyn
	-------Oil content† (%)-----		---Protein content† (%) ---		Crude fibre content† (%)	
			Seed			
Control	50.9a*	38.7a	13.9a	21.3a	17.2a	20.2a
SB	50.6a	40.1a	13.0a	21.2a	17.4a	19.5a
SCB	51.0a	40.8a	13.5a	20.8a	17.3a	19.8a
			Kernel			
Control	65.7a	54.6a	17.2a	29.1a	2.6a	2.3a
SB	66.1a	56.1a	16.0a	27.9a	2.3a	2.3a
SCB	65.4a	56.7a	16.6a	27.2a	2.4a	2.2a

†Moisture-free basis.

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

Table 29 The potentially recoverable oil, yield of the kernel-rich fraction (KRF) and the protein and crude fibre contents of the KRF of sunflower as affected by fertilisation with sodium borate (SB) and sodium calcium borate (SCB) at two localities.

Treatment	------ Locality ------	
	Bethlehem	Petrus Steyn
	Potentially recoverable oil (g per 100 g seed‡)	
Control	43.8a*	35.8a
SB	44.1a	37.1a
SCB	45.5a	37.8a

Continued overleaf

Table 29 continued

Treatment	------ Locality ------	
	Bethlehem	Petrus Steyn
	------ KRF yield † (g per 100 g seed) ------	
Control	30.1b	34.3a
SB	29.7b	32.5a
SCB	32.3a	33.6a
	----- KRF protein content † (%) -----	
Control	39.5a	55.8a
SB	37.2ab	57.2a
SCB	36.4b	55.2a
	---- KRF crude fibre content † (%) ----	
Control	21.7a	11.1a
SB	22.7a	12.5a
SCB	21.9a	12.7a

‡ Moisture-free basis.

†Oil and moisture-free basis.

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

DISCUSSION AND CONCLUSIONS

The mean seed oil contents of 50.8 and 39.9 for Bethlehem and Petrus Steyn respectively, compares well with the mean maximum and minimum values of 52.6 and 41.2% found for environments in Chapter 4 (Table 18). The potentially recoverable oil of the seed produced at Petrus Steyn (36.9 g per 100 g seed) was poor and approximately 17% lower than that of the seed produced at Bethlehem (445 g kg^{-1}). The KRF protein content at Petrus Steyn was extremely high and almost 1.5 times that for the KRF produced from the Bethlehem seed. Despite the relatively high hullability of the seed produced at Bethlehem, the KRF protein content of 37.7% is below, and the crude fibre content of 22.1% is above the statutory moisture-free limits of 44.4 and 17.8% respectively.

The reactions of sunflower yield and seed characteristics to B fertilisation are inconsistent. Yield increases were anticipated at both localities as B deficiency symptoms are often observed in these areas. Leaf analyses indicated neither deficiency nor toxicity. The results however, are not unique as yield reductions due to B fertilisation have been reported (FSSA, 1977; Hilton & Zubriski, 1985).

The lack of consistency in the reaction of the seed yield and hullability to B fertilisation may be due to the large difference in soil fertility between the two localities (Table 26) and the fact that soil moisture status, temperature and even light intensity affect the uptake of B (Moraghan & Mascagni, 1991). What is more, published B deficiency (and most likely also toxicity) limits are not in agreement. Using solution culture experiments, the critical concentration for deficiency was determined as 190 mg kg^{-1} by Blamey *et al.* (1997) which is more than five times the limit of 34 mg kg^{-1} determined through field trials (Blamey *et al.*, 1979; Fernandez *et al.*, 1985).

The inconsistent results are probably due to the fact that the effect of B deficiency on plants is not well understood, as stated by Moraghan & Mascagni (1991), and the fact that so many environmental variables affect the uptake of B. Although differences between treatments were small and no boron deficiency was observed, the indications are that apart from yield, B supply can also affect hullability and consequently oil cake quality.