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Zinc deficiency in navy beans in the Dawson–Callide. 2. Response to zinc application in the field

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Summary

The response to zinc application in the field was studied in two varieties of navy beans on light and heavy textured Callide alluvium. The heavy textured site was non-responsive. On the light soil, zinc application (10 kg Zn/ha) increased yield in Selection 46 from 633 kg/ha to 813 kg/ha, and increased zinc concentration of youngest fully expanded laminae from 9.4 ppm to 19.8 ppm. For cultivar Gallaroy, zinc application increased yield from 53 kg/ha to 120 kg/ha, failed to eliminate deficiency symptoms, and failed to increase zinc concentration of youngest fully expanded laminae above 13.5 ppm. It was concluded that the relative insensitivity to zinc deficiency in Selection 46 was of practical significance, and that selection for this character may be a worthwhile breeding objective.

INTRODUCTION

In the previous paper (Wade 1985), a disorder of navy beans suspected to be zinc deficiency was confirmed with the aid of soil analyses, the observation of visual symptoms and a nutrient omission pot trial. In this study, a field experiment involving two rates of zinc, two varieties of navy beans and two sites was conducted to determine:

(a) the field response to zinc application,

(b) cultivar variation in sensitivity to zinc deficiency,

(c) whether such variation in sensitivity is of practical significance.

MATERIALS AND METHODS

Two field trials were conducted at Biloela Research Station on the light and heavy textured soils of the Callide alluvium, which were utilised in an earlier pot trial (Wade 1985). Each experiment consisted of two rates of zinc as zinc sulphate heptahydrate (0 and 10 kg Zn/ha) and two varieties (Gallaroy and Selection 46) in a factorial design with five replicates. A split plot design was used, with zinc treatments as main plots. No basal fertiliser dressing was applied. The zinc fertiliser was broadcast by hand and incorporated with a combine drill just before planting. Uninoculated seed was used for reasons discussed elsewhere (Wade 1985). The trial was planted in 75 cm rows with a cone planter and the crop was thinned after emergence to 110 000 plants/ha. Eight row plots of 12 m were planted on the heavy soil and six row plots of 12 m were planted on the light soil on February 10 and 28 respectively. Pests and diseases were controlled. The crops were sidedressed with urea (30 kg N/ha) on March 20, and received supplementary irrigation as required in dry periods.

Dry matter production at flowering was recorded from 1 m samples of row collected at random on March 17 and April 30 for the heavy and light soils respectively. Final grain yield was recorded on June 20 from a 12 m^2 datum area per plot, consisting of two rows of 8 m. Whole pods were collected from 1 m samples of row at maturity for the measurement of yield components.

Youngest fully expanded laminae were selected prior to flowering from six plants in each treatment on both soils for the determination of zinc concentration. Laminae were oven dried at 60°C for at least 48 hours. A nitric acid-perchloric acid digestion was used (Johnson and Ulrich 1959), and zinc in the digests was measured using a Varian Techtron AA6 atomic absorption spectrophotometer at a wavelength of 213.9 nm.

RESULTS

From February 13 to 20, 91 mm of rain fell, which resulted in flooding on the heavy soil. Mild symptoms of nitrogen deficiency were observed on this site prior to the sidedressing of nitrogen. The rain which fell in mid February delayed planting on the light soil for 18 days. This crop was free of the problems encountered on the heavy soil, and was spray irrigated on April 8, so that soil moisture at flowering was optimal (Table 1).

Table 1. Gravimetric soil moisture percentages at flowering on the heavy and light textured soils of the Callide alluvium, and their percentages at field capacity and wilting point

Soil texture	Gravimetric soil moisture percentage		
	At flowering	At field capacity	At wilting point
Heavy	15	24	12
Light	18	18	9

Symptoms

On the heavy soil, some interveinal chlorosis was observed on recently matured leaves in both varieties. The symptoms were more severe in Gallaroy than in Selection 46. No visual response to zinc application was observed in either variety. The zinc deficiency symptoms were present in all plots during the vegetative phase, but declined by flowering.

On the light soil, severe deficiency symptoms occurred in Gallaroy. Interveinal chlorosis and necrosis occurred on all leaves in the untreated plots. Zinc application resulted in larger plants with more flowers, but failed to fully eliminate leaf symptoms. No symptoms were present in off-types of Gallaroy which had a vining habit. In contrast to Gallaroy, few symptoms were observed in Selection 46. Some plants in the untreated plots showed mild interveinal chlorosis on the older leaves. Zinc application completely eliminated symptoms in this variety.

Zinc concentration in youngest fully expanded laminae

Table 2. The concentrations of zinc on a dry weight basis in the youngest fully expanded leaves at flowering in two varieties of navy beans grown on heavy and light textured Callide alluvium at two rates of zinc application

Soil texture and zinc application	Leaf zinc concentration (ppm)	
	Gallaroy	Selection 46
Heavy soil		
0 kg Zn/ha	15.0	27.5
10 kg Zn/ha	17.5	26.3
Light soil		
0 kg Zn/ha	8.6	9.4
10 kg Zn/ha	13.5	19.8

On the heavy soil, the varieties differed in zinc concentration, which showed little response to the application of 10 kg Zn/ha (Table 2). Zinc concentration in the index leaves was higher for Selection 46 than Gallaroy. On the light soil, zinc application increased zinc concentration in the index leaves, especially for Selection 46. In the absence of applied zinc, the varieties had similar zinc concentrations (9.0 ppm), but zinc application increased the concentrations to 13.5 ppm and 19.8 ppm for Gallaroy and Selection 46 respectively.

Flowering

Flowering was delayed 17 days on average by late planting on the light soil (Table 3). Selection 46 flowered later than Gallaroy, with the difference being reduced by late seeding from 7 to 2 days. Flowering date was unaffected by zinc application.

Table 3. The number of days to flowering for two varieties of navy beans on heavy and light textured Callide alluvium

Soil texture	Planting date	Time of flowering (days after planting)	
		Gallaroy	Selection 46
Heavy soil	10 Feb.	26	33
Light soil..	28 Feb.	45	47

Dry weight, yield and yield components

On the heavy soil, there was a significant varietal difference in dry matter accumulation at flowering, but no significant response to zinc (Table 4). Selection 46 produced more dry matter at flowering than Gallaroy. However, there were no significant differences in grain yield (Table 4), nor in yield components at maturity (data not presented).

Table 4. Total dry weight at flowering and grain yield at maturity for two varieties of navy beans at two rates of zinc application on the heavy soil

Cultivar and treatment	Dry weight at flowering (kg/ha)	Grain yield at maturity (kg/ha)
Gallaroy		
0 kg Zn/ha	556	1000
10 kg Zn/ha	645	1013
Selection 46		
0 kg Zn/ha	685	1213
10 kg Zn/ha	865	1227
l.s.d. (Var×Zn)		
(P=0.05)	212	380
(P=0.01)	297	533

On the light soil, the varieties differed in dry weight at 10 days after flowering, while zinc application increased growth in both (Table 5). The absolute improvement in growth and grain yield with zinc application was much greater in Selection 46. In relative terms the improvement in growth and grain yield with zinc application was much greater in Gallaroy.Zinc application resulted in significantly more seeds per pod, and in larger grains. Selection 46 had larger grains than Gallaroy, and had significantly more seeds per plant, pods per plant and seeds per pod.

DISCUSSION

Index leaf zinc concentrations and deficiency symptoms

Zinc deficiency occurs in many plants, including soybeans, when the leaf concentration is less than 20 ppm in the dry matter (Mortvedt *et al.* 1972). Viets *et al.* (1954) showed that deficiency symptoms occurred in field beans when the upper mature leaves contained less than 20 ppm zinc. Highest yields of beans have been reported with youngest fully expanded leaf zinc concentrations of 25 to 34 ppm (Melton 1969), with yield being reduced at less than 20 ppm (Boawn *et al.* 1969; Melton *et al.* 1970). The international bean programme in Columbia (CIAT 1977) has reported a critical zinc concentration for deficiency in the upper leaves at flower initiation of 17 ppm in the varieties ICA Gauli and Porrillo Sintetico. No reference was found which stated a definite critical level for zinc in navy beans, so the critical level in youngest fully expanded mature laminae is taken as 17 to 20 ppm.

Table 5. Total dry weight at 10 days after flowering and grain yield and yield components at maturity for two varieties of navy beans at two rates of zinc application on the light soil

Cultivar and treatment	Dry weight (kg/ha)	Grain yield (kg/ha)	Seeds per plant	Pods per plant	Seeds per pod	100 Seed weight (g)
Gallaroy						
0 kg Zn/ha	273	53	8.7	3.9	1.7	12.2
10 kg Zn/ha	525	120	20.9	7.2	2.7	15.2
Selection 46						
0 kg Zn/ha	1420	633	66.4	18.2	3.6	15.0
10 kg Zn/ha	1976	813	84.3	20.6	4.1	14.7
l.s.d. (Var×Zn)						
(P=0.05)	262	85	22.2	4.7	1.1	3.5
(P=0.01)	382	123	32.2	6.8	1.6	5.1

On this basis, zinc concentrations in index leaves of Selection 46 may be considered on the heavy soil as adequate, on the light soil with zinc fertilisation as barely satisfactory, but on the light soil, in the absence of applied zinc, as deficient. Very few symptoms were observed in this variety, even in the absence of applied zinc on the light soil, when the concentration in the index leaves was 9.4 ppm.

For Gallaroy, leaf zinc concentrations ranged from deficient on the light soil in the absence of applied zinc (8.6 ppm) to marginal on the heavy soil with applied zinc (17.5 ppm). Over that range, symptoms varied from severe (stunting, interveinal chlorosis and necrosis) to mild (interveinal chlorosis on the older leaves in the vegetative phase).

The symptoms attributed to zinc deficiency in the field agree with those described by Sprague (1964), Gallagher (1972), and Brouwer *et al.* (1975), and with those reported by Wade (1985). The severity of the symptoms in both varieties increased as leaf zinc concentration decreased, but to a greater extent in Gallaroy.

Flowering was delayed on average by 17 days following the 18 day delay in seeding on the light soil (Table 3).Boawn *et al.* (1969) reported that delayed maturity was associated with lower leaf zinc concentrations in field beans, but this response was not observed in this study.

Dry weight, yield and yield components

On the heavy soil, no significant yield responses to zinc application were obtained, although index leaf zinc concentration in Gallaroy increased by 2.5 ppm to 17.5 ppm, a level regarded as marginal. Some zinc response may have occurred in Gallaroy in the absence of the waterlogging and nitrogen deficiency problems encountered early in the vegetative phase on this site. The wet conditions may also have contributed to the development of zinc deficiency symptoms early in the life cycle (Mortvedt *et al.* 1972). Alternatively, as the plants grew, the roots reached greater soil depth and exploited larger soil volume to obtain sufficient zinc.The lack of response in this soil supports the results of the earlier pot trial (Wade 1985).

On the light soil, Selection 46 yielded satisfactorily in comparison with previous local experience (Bath 1975), and produced very few deficiency symptoms, even in the absence of applied zinc when leaf zinc concentrations were low. Zinc application increased its yield, increased its index leaf zinc concentrations and eliminated deficiency symptoms. In contrast, zinc application failed to produce satisfactory yields of Gallaroy on the light soil, failed to eliminate deficiency symptoms and failed to increase leaf zinc concentrations to adequate levels.

These results support the conclusions from the nutrient omission pot trial (Wade 1985), that plant height and dry matter production were reduced in the absense of zinc application on the light soil (0.94 ppm EDTA-ammonium carbonate extractable zinc), but not on the heavy soil (2.56 ppm EDTA-ammonium carbonate extractable zinc). Gallaroy was again more sensitive than Selection 46.

Genotypic sensitivity to zinc deficiency

Variation in genotypic sensitivity to zinc deficiency was established in this study. This result supports the conclusions of Brouwer *et al.* (1981), who reported that cultivars Kerman and Gallaroy were very sensitive, while certain selections from the Actopan×Sanilac cross were relatively insensitive.

Both varieties studied have the common parent Sanilac. Gallaroy was selected from a cross with California Small White, and Selection 46 from a cross with Actopan (Gallagher 1972; Redden *et al.* 1985). At low external zinc supply, Sanilac has been reported to grow poorly (Ambler and Brown 1969; Jyung *et al.* 1972), to be less responsive to additional zinc (Mugwira and Knezek 1971) and to be more adversely affected by excessive external supply of zinc (Polson and Adams 1970) than other cultivars. In a screening trial on a low zinc soil at Hermitage Research Station, Actopan and California Small White were both relatively insensitive to zinc deficiency, while Sanilac was sensitive (R.J. Redden, pers. comm. 1985). Thus, varying levels of sensitivity to zinc deficiency may occur in selections from both crosses (California Small White×Sanilac and Actopan×Sanilac).In the latter, Selection 39 (Actolac) was more sensitive than Selection 51 (Actosan) and Selection 46 (Brouwer *et al.* 1981; Redden *et al.* 1985).

The insensitivity to zinc deficiency in Selection 46 is considered a useful attribute, since even under conditions of low available zinc, satisfactory yields were attained in the absence of zinc fertilisation. These results suggest that selection for insensitivity to zinc deficiency may be a worthwhile breeding objective.Recently, navy bean breeders have incorporated selection for insensitivity to zinc deficiency into their programmes (Redden *et al.* 1985).

Soil zinc application technology

Zinc is extremely immobile in alkaline soils (Brown *et al.* 1962; Mortvedt and Giordano 1967). The distribution of applied zinc through the soil profile is more important than its solubility (Allen and Terman 1966), necessitating its early application and thorough deep incorporation (Whitehouse *et al.* 1973).

A higher rate of zinc (20–30 kg Zn/ha) than that used in this study has been considered necessary for navy beans on Darling Downs black earths, especially when granulated rather than powdered forms of fertiliser were applied (Leslie *et al.* 1973). Other studies have reported application rates as low as 3.6 kg Zn/ha sufficient for controlling zinc deficiency on the same soils (Leslie and Whitehouse 1969). This discrepancy has been attributed to a sulphur response by Radjagukguk *et al.* (1980), or to the form, timing and distribution of applied zinc in the profile (Leslie *et al.* 1973 ; Whitehouse *et al.* 1973). As no sulphur response was obtained in the earlier pot trial (Wade 1985), the failure of zinc application to optimise yields and eliminate zinc deficiency symptoms is attributed to the inadequacy of zinc incorporation. A higher rate of zinc application with better incorporation may be necessary to optimise yields of Gallaroy on the light soil.

This should be tested by studying the yield responses of navy bean varieties Gallaroy and Selection 46 to rates of zinc and sulphur application on the light soil. Such an experiment could also be used to assist the selection of lines insensitive to zinc deficiency. Breeding materials could be screened across this set of treatments in comparison with the sensitive and insensitive checks Gallaroy and Selection 46. Selection for insensitivity to zinc deficiency is considered a worthwhile breeding objective.

CONCLUSIONS

The application of zinc at 10 kg Zn/ha resulted in significant yield responses in navy bean varieties Gallaroy and Selection 46 on light textured Callide alluvium. Zinc application neither completely eliminated zinc deficiency symptoms in Gallaroy, nor increased its yield to an acceptable level. The relative insensitivity to zinc deficiency in Selection 46 suggests that selection for this character may be worthwhile.

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