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# Zinc deficiency in navy beans in the Dawson–Callide. 1. Diagnosis of the disorder

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## Summary

A disorder suspected to be zinc deficiency was observed in crops of cotton, linseed and navy beans in the Dawson Callide. The problem was studied using soil analyses, the observation of visual symptoms and a nutrient omission pot trial with the navy bean varieties Gallaroy and Selection 46.

Soil analyses revealed light textured Callide alluvium had a pH of 6.28 and contained 0.94 ppm EDTA-ammonium carbonate extractable zinc. Symptoms of zinc deficiency obtained in solution culture were consistent with those obtained in the minus zinc treatment in the pot trial. The reduction in plant height and dry matter production in the minus zinc treatment was more pronounced in Gallaroy than in Selection 46. The diagnosis of zinc deficiency was confirmed.

## INTRODUCTION

In the Callide and Dawson districts, symptoms suspected to be zinc deficiency have been observed in cotton and linseed (J. E. Rawson, pers. comm. 1973) and navy beans (Gallagher 1972). In navy bean variety trials at Biloela Research Station, the symptoms were more severe in the standard varieties Kerman and Gallaroy than in certain selections of the cross between the varieties Actopan and Sanilac. Yields from the standard varieties were poor (Bath 1975). This unidentified disorder may seriously restrict navy bean production in the Callide and Dawson districts.

In this paper, I report the diagnosis of the disorder using soil analyses, the observation of deficiency symptoms and a nutrient omission pot trial.

## MATERIALS AND METHODS

### Soil description and analysis

Two sites were selected at Biloela Research Station on the heavy textured (block Q6) and light textured (block U) soils of the Callide alluvium. The soils of the Callide alluvial plain typically range from sandy surfaced dark friable earths at the levee bank, through fine sandy to sandy loam surfaced duplex soils, to very dark non-cracking and cracking clays (A. A. Webb, pers. comm. 1985). The heavy soil chosen was a very dark non-cracking clay (Uf 6.33, Northcote 1971) and the light soil chosen was a sandy loam surfaced duplex (Dd 1.13, Northcote 1971). These soils typically contain more than 100 ppm bicarbonate extractable phosphorus ( A.A. Webb, pers. comm. 1985).

For each site, soil samples (0–10cm) were air-dried, sieved through a 1cm polyethylene screen and mixed thoroughly. Soil pH was measured in 1:2 soil:0.01 M calcium chloride. Extractable zinc was measured using 0.01 M EDTA-1.0 M ammonium carbonate (Trierweiler and Lindsay 1969). Moisture contents at field capacity were determined using the column method with a 48 hour drainage time (Veihmeyer and Hendrickson 1950).

### Pot trial

A nutrient omission pot trial was conducted on both the light textured and heavy textured Callide alluvial soils, in which two varieties (Gallaroy and Selection 46) and four nutrient treatments were in a factorial design with three replicates. The nutrient treatments selected were: no applied nutrients (Nil); all nutrients (All) including N, P, K, S, and Zn; all nutrients except sulphur (All−S) and all nutrients except zinc (All−Zn). The 48 pots were fully randomised within soil types.

Plastic-lined polyethylene pots, 15 cm in diameter, were each filled with 1200 g of air-dry soil. The nutrients were applied as ammonium nitrate, dipotassium phosphate, zinc sulphate and sodium sulphate at the rates indicated in Table 1. Additional sulphur as sodium sulphate was applied to the minus zinc pots to equalise sulphur additions to the treated pots. Nutrients were added separately in solution and applied evenly over the soil surface. After each nutrient addition, 10 mL of deionised water was applied.

**Table 1. Rates of application of the nutrients N, P, K, S and Zn**

| Element | Rate of element applied | |
|---|---|---|
| | kg/ha | mg/pot |
| N | 142 | 219 |
| P | 69 | 106 |
| K | 171 | 264 |
| S | 90 | 138 |
| Zn | 36 | 56 |

Eight uninoculated seeds were planted into each pot on August 3. One week later, the number of plants in each pot was reduced to four. Deionised water was added to the pots at least once per day to maintain the moisture content of the soils at approximately field capacity throughout the experiment. Two sidedressings of ammonium nitrate (5 kg N/ha) were applied to the treated pots on September 8 and 15. Symptom development was observed throughout the study. Heights to the growing point and dry matter yields were recorded at harvest on September 21.

### Solution culture

The navy bean cultivars Gallaroy and Selection 46 were grown in solution culture in the glasshouse. Seeds were germinated in sand and seedlings transferred to pots containing complete and low zinc nutrient solutions (0.23 and 0.02 μM zinc respectively).The techniques were described elsewhere (Forno *et al.* 1975).Plants were harvested 37 days after germination. Symptom development was observed for each variety.

## RESULTS

### Solution culture

In solution culture, both varieties in the low zinc treatment were severely stunted with respect to the controls. Interveinal chlorosis began at the base of the lower leaves before spreading towards their tips, and occurred in a like manner on successively younger leaves with time. Subsequently necrotic regions occurred between the veins in a similar pattern of development. Leaves once senesced were shed. The only varietal difference was increased basal branching in Gallaroy.

### Soil analysis

Soil analysis results are presented in Table 2. The light textured soil had a lower level of EDTA-ammonium carbonate extractable zinc, a higher soil pH and a lower moisture content at field capacity than the heavy textured soil.

### Pot trial

In the nutrient omission pot trial, anthesis occurred in Gallaroy on September 6 and in Selection 46 six days later. Time of flowering was not affected by nutrient treatment.

On both soils, less growth occurred in the zero applied nutrient treatment, in which a general leaf chlorosis, followed by leaf necrosis, commenced on the older leaves. No effectively nodulated plants were found.

**Table 2. Soil pH, EDTA-ammonium carbonate extractable zinc concentration and gravimetric soil moisture percentage at field capacity for light and heavy textured Callide alluvium**

| Measurement | Heavy soil | Light soil |
|---|---|---|
| Soil pH[1] | 6.05 | 6.28 |
| EDTA-ammonium carbonateextractable zinc (ppm)[2] | 2.56 | 0.94 |
| Gravimetric soil moisturetpercentage at field capacity[3] | 24.0 | 18.0 |

[1] 1 : 2 soil: 0.01 M calcium chloride.

[2] Trierweiler and Lindsay (1969).

[3] Veihmeyer and Hendrickson (1950).

Late in the vegetative phase, plants of both varieties growing in the minus zinc treatment on the light soil were observed to be stunted. In Gallaroy only, interveinal chlorosis occurred on the older leaves and fewer flowers were produced. No leaf symptoms were present in Selection 46.

Heights to the growing point are presented in Table 3. Plant height was reduced in the absence of applied nutrients. The absense of applied zinc did not significantly influence plant height on the heavy soil in either variety. In the absence of applied zinc on the light soil however, plant height was significantly reduced, particularly in Gallaroy.

**Table 3. Heights to the growing point at harvest for the navy bean cultivars Gallaroy and Selection 46 on heavy and light textured Callide alluvium in four nutrient treatments in the pot trial**

| Soil texture and cultivar | Plant height (cm) | | | |
|---|---|---|---|---|
| | Nil | All | All−S | All−Zn |
| Heavy soil | | | | |
| Gallaroy | 18.0 | 28.7 | 27.7 | 28.3 |
| Selection 46 | 12.7 | 17.7 | 18.3 | 17.3 |
| Light soil | | | | |
| Gallaory | 15.3 | 24.3 | 26.7 | 17.0 |
| Selection 46 | 11.3 | 18.0 | 18.7 | 15.0 |

l.s.d. (Var×Treat×Soil): 5.8 ($P$=0.05); 7.9 ($P$=0.01)

Dry matter yields are presented in Table 4. Less dry matter was accumulated in the absense of applied nutrients. The absense of applied zinc did not significantly influence dry matter production on the heavy soil in either variety. In the absense of applied zinc on the light soil however, dry matter production was reduced in comparison with plants receiving both nitrogen and zinc, for Gallaroy only.

## DISCUSSION

### Nitrogen deficiency

In the absense of fully effective nodulation in the pot trial, the symptoms in the zero applied nutrient treatment were attributed to nitrogen deficiency. Navy beans are normally grown with applications of nitrogen fertiliser (Kerr 1972; Gunton 1982). Because of the inability of navy beans to effectively nodulate consistently, rhizobial nitrogen has not been a reliable substitute for fertiliser nitrogen (Diatloff and Saint-Smith 1981; Huch *et al.* 1983). Consequently, uninoculated seed was sown in this trial, and a non-limiting dose of nitrogen (142 kg/ha) was applied to the treated pots. The two sidedressings of nitrogen were applied to the treated pots to ensure no limitation of that element occurred during the trial.

**Table 4. Dry matter yields at harvest for the navy bean cultivars Gallaroy and Selection 46 on heavy and light textured Callide alluvium in four nutrient treatments in the pot trial**

| Soil texture and cultivar | Dry matter yields (g/pot) | | | |
|---|---|---|---|---|
| | Nil | All | All−S | All−Zn |
| Heavy soil | | | | |
| Gallaroy | 3.0 | 16.0 | 15.8 | 15.9 |
| Selection 46 | 4.7 | 16.7 | 16.8 | 17.4 |
| Light soil | | | | |
| Gallaroy | 2.5 | 10.6 | 13.8 | 8.0 |
| Selection 46 | 4.1 | 13.7 | 15.7 | 14.5 |

l.s.d. (Var×Treat×Soil): 4.7 ($P$=0.05); 6.3 ($P$=0.01)

## Zinc deficiency

Zinc deficiency may result from low total soil zinc or from its unavailability as a result of alkalinity, liming, high soil phosphorus content, phosphorus or nitrogen fertiliser application, or long fallow (Mortvedt *et al.* 1972). Both soils studied had pH levels greater than six, the level at which these authors considered zinc availability declined.

Trierweiler and Lindsay (1969) reported that a critical value of 1.4 ppm EDTA-ammonium carbonate extractable zinc separated zinc deficient from non-deficient Colorado soils. Examination of their data suggests that symptoms in maize may not appear unless the soil test was less than 1.25 ppm. They also showed that the critical extractable zinc level for soils without addition of phosphate fertiliser, beyond the level considered adequate for plant growth, was about 1.0 ppm. This indicates the dependence of the critical extractable zinc level on the level of available soil phosphorus.

Radjagukguk *et al.* (1980) reported that the best separation of deficient and marginally deficient soils from non-deficient soils for young wheat plants in Darling Downs black earths was obtained by using a critical value of 0.61 ppm EDTA-ammonium carbonate extractable zinc. The lower sensitivity to zinc deficiency of wheat than maize and beans (Chapman 1966), would account in part for the lower critical value they reported. All of the soils they studied were adjusted to the bicarbonate extractable phosphorus sufficiency threshold of 45 ppm (Whitehouse 1972). For navy beans on the very high phosphate soils of the Callide alluvial plain (A. A. Webb, pers. comm. 1985), a higher critical value of EDTA-ammonium carbonate extractable zinc would be expected. In this paper, the critical value is taken as 1.0 ppm, which is intermediate between the values of Radjagukguk *et al.* (1980) and Trierweiler and Lindsay (1969).

Thus the light textured soil with 0.94 ppm EDTA-ammonium carbonate extractable zinc and a pH of 6.28 is considered marginal in zinc availability. Since beans are a good indicator species for zinc deficiency (Chapman 1966), deficiency symptoms and reduced growth and yield may result.

On the light soil in the pot trial, the symptoms of zinc deficiency obtained in the minus zinc treatment are consistent with those obtained in low zinc solution culture, and with those described for beans (Sprague 1964) and for navy beans (Gallagher 1972; Brouwer *et al.* 1975). In low zinc solution culture, both varieties showed acute zinc deficiency symptoms, but excessive branching was evident only in Gallaroy. In the pot trial, zinc deficiency symptoms were less severe in Selection 46 than Gallaroy. Only Gallaroy developed interveinal chlorosis.

Less growth was recorded on the light soil, which had a lower level of EDTA-ammonium carbonate extractable zinc. In the absence of applied zinc on this soil, plant heights were significantly reduced in both varieties. In variety Gallaroy only, dry matter accumulation was reduced in comparison with plants receiving both nitrogen and zinc. These results confirm the diagnosis of zinc deficiency. Gallaroy was more sensitive to zinc deficiency than Selection 46. This difference in varietal sensitivity is consistent with field observations at two sites; Biloela (Bath 1975) and Emu Vale (Brouwer *et al.* 1981), which both involved a range of navy bean varieties, including Gallaroy and Selection 46. The response to zinc application in the field is reported in Wade and Bath (1985).

## CONCLUSIONS

Zinc deficiency may occur in sensitive crops on the light textured Callide alluvial soil, which contained 0.94 ppm EDTA-ammonium carbonate extractable zinc. The diagnosis of zinc deficiency was confirmed. Gallaroy was more sensitive than Selection 46. The response to zinc application in the field is reported in paper 2.

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