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Differential varietal response to zinc foliar sprays in navy beans (Phaseolus vulgaris)

H. M. Brouwer, Dip. Trop. Agric., G. R. Stevens, Q.D.A., and J. G. Fletcher, Q.D.A.

Summary

Rain-grown trials were conducted from 1973 to 1975 on the southern Darling Downs to assess the effects on yield of foliar applications of zinc sulphate heptahydrate on five navy bean cultivars.

Yield increases of up to 86% were obtained, though varietal responses to zinc application varied markedly. Dry seed beans harvested from zinc sprayed treatments accumulated significantly higher zinc levels than beans from control plots. Severity of zinc deficiency symptoms early in the season correlated significantly with yields obtained at the end of the season.

1. Introduction

Navy beans (*Phaseolus vulgaris*) are reported as being especially sensitive to zinc deficiency (Anon. 1973). Some navy bean crops on the southern Darling Downs grow poorly giving yields less than expected. The plants produce leaves with distinct interveinal chlorosis, flowering is prolonged and pod and seed set is poor. These symptoms indicate zinc deficiency.

Whitehouse (1973) observed that the Darling Downs black earths were potentially zinc deficient. He showed that cultural factors such as fallow length could influence the expression of zinc deficiency while not apparently affecting extractable soil zinc.

From applied fertilizer studies, Leslie, Whitehouse and MacKenzie (1973) showed that the level of available zinc related to total zinc addition and was little affected by time elapsing after application. Fixation of zinc did not, therefore, occur and any plant deficiency symptoms could not be attributed to this cause.

These conclusions conflict with those of other workers who maintain that substances in the soil can and do affect the availability of zinc (Hudson and Cradock 1953; Edwards and Kamprath 1974; Anon 1973).

Pauli, Roscoe and Moser (1968), working with navy beans, found that high soil phosphorus levels resulted in zinc deficiency and low zinc concentrations in leaves and seed. They concluded, however, that the phosphorus-zinc interaction was not in the soil external to the plant.

Zinc deficiency symptoms therefore exist in a particular crop for reasons which may be extremely complex.

The aim of this work was to determine whether zinc deficiency in beans (and consequent reduced yields) could be alleviated by foliar applications of zinc sprays. This method of application eliminates the complication of zinc-soil interactions, though it has the disadvantage that sprays were found by Leslie, Whitehouse and MacKenzie (1973) to be inferior to adequate soil dressing.

2. Materials and methods

Navy beans for the experiments were grown in an alluvial dark cracking clay (Ug 5.15) (Northcote 1971) at Emu Vale during the 1973-74 and 1974-75 seasons.

Before planting 0 to 10 cm soil from the experimental area was analysed. Soil characteristics in the 1973-74 season were:

pH (1:5 water)	6.1 to 6.5
nitrate—N (1:5 water, specific ion electrode)	20 to 53 ppm
BSES—P (Kerr and von Stieglitz, 1938)	>150 ppm
K (von Stieglitz, 1953)	0.70 to 0.76 meg %
DTPA—Zn (Lindsay and Norvell 1969)	0.9 to 1.4 ppm

During the 1974-75 season soil values were similar except that nitrate—N was lower (5 ppm) and Zn levels higher (1.6 to 2.1 ppm).

The cultivars used in the experiments were Selection 51, Selection 46, Selection 39, Gallaroy and Kerman.

Zinc was provided as zinc sulphate heptahydrate sprays at 100 L ha^{-1} of a 1% solution (1 kg ha^{-1}). In the first season, sprays were applied 14 and 28 days after emergence. In the second season, they were applied 10, 24 and 38 days after emergence. The surfactant 'Agral 60' at 15 mL ha^{-1} (0.01%) was added to each made-up spray.

Plots of three rows, at 70-cm inter-row spacing, were 22 m long. They were machine sown with the three-row Cone Planter. The datum area consisted of 18 m of the centre row of each plot.

The plants were rated for zinc deficiency on a 1-to-5 scale with '1' indicating no symptoms and '5' indicating severe symptoms. In the 1973-74 season these ratings were recorded 7 and 8.5 weeks after planting, while in the 1974-75 season they were recorded 6.5 and 8.5 weeks after planting.

The plants were hand harvested and threshed in a mobile threshing machine, and the seed was cleaned with a Boddington grader. Yields were expressed in kg ha^{-1}.

Seed samples from plots were analysed for nitrogen and zinc contents using Kjeldahl and X-ray fluorescence methods respectively.

3. Results

Weather in 1973-74 was suitable for navy bean production but dry weather during the flowering period in February caused some flower abortion. In the 1974-75 season weather was suitable throughout the growing season and higher seed yields were produced.

Table 1 presents the seed yields obtained in both years. Large differences in yield between varieties in the absence of zinc were greatly reduced when zinc sprays were applied. This was due to the relative lack of response to zinc sprays by the two highest yielding cultivars, Selection 51 and Selection 46.

There was little difference between cultivars, and between zinc treatments, in the nitrogen content of the seed. Protein yield per hectare was therefore closely allied to seed yield per hectare.

Mean zinc deficiency ratings for the 1973-74 season are shown in table 2. Relatively severe zinc deficiency symptoms were found in three of the five cultivars tested, including the commercial cultivars Kerman and Gallaroy. These symptoms were significantly reduced when zinc sprays were used. The other two cultivars, Selection 51 and Selection 46, showed only marginal zinc deficiency symptoms in all plants with or without zinc sprays.

Mean zinc deficiency ratings for the 1974-75 season are given in table 3. Although the severity of the zinc deficiency symptoms was lower in this season than in the 1973-74 season, significant differences occurred between cultivars and between zinc treatments.

Seed zinc concentration values presented in table 4 show that the zinc concentration in the seed increased significantly when the zinc sprays were applied. There was significant variation in seed zinc content between cultivars irrespective of zinc spray application.

Table 1. Mean seed yields (kg ha^{-1} at 14% moisture)

Cultivar	1973–74			1974–75		
	B_0 nil zinc	B_1 with zinc	Means	B_0 nil zinc	B_1 with zinc	Means
A_0 Kerman	1 049	1 955	1 502	1 412	2 285	1 848
A_1 Gallaroy	975	1 337	1 156	2 276	2 740	2 508
A_2 Selection 39	1 491	2 066	1 779	2 616	2 912	2 764
A_3 Selection 51	2 259	2 437	2 348	2 987	3 161	3 074
A_4 Selection 46	2 260	2 240	2 250	2 932	3 095	3 013
Means	1 607	2 007		2 445	2 838	
LSD: A factor (cultivars)	5% = 143; 1% = 193			5% = 283; 1% = 381		
B factor (zinc)	5% = 91; 1% = 122			5% = 179; 1% = 241		
AB interaction	5% = 203; 1% = 274					

Table 2. Mean zinc deficiency ratings* (1973–74 season)

Cultivar	7 weeks after planting			8.5 weeks after planting		
	B_0 nil zinc	B_1 with zinc	Means	B_0 nil zinc	B_1 with zinc	Means
A_0 Kerman	4.0	3.1	3.5	4.5	3.5	4.0
A_1 Gallaroy	5.0	4.3	4.7	5.0	4.2	4.6
A_2 Selection 39	3.7	1.9	2.8	4.8	3.1	3.9
A_3 Selection 51	1.2	1.1	1.2	1.8	1.3	1.5
A_4 Selection 46	1.6	1.5	1.5	2.8	2.4	2.6
Means	3.1	2.4		3.8	2.9	
LSD: A factor	5% = 0.4; 1% = 0.5			5% = 0.5; 1% = 0.7		
B factor	5% = 0.2; 1% = 0.3			5% = 0.3; 1% = 0.4		
AB interaction	5% = 0.5; 1% = 0.7					

* 1 = no symptoms; 5 = severe symptoms.

Table 3. Mean zinc deficiency ratings* (1974–75 season)

Cultivar	6.5 weeks after planting			8.5 weeks after planting		
	B_0 nil zinc	B_1 with zinc	Means	B_0 nil zinc	B_1 with zinc	Means
A_0 Kerman	2.7	1.4	2.0	4.2	1.6	2.9
A_1 Gallaroy	3.8	1.6	2.7	4.7	1.8	3.2
A_2 Selection 39	2.6	1.5	2.0	3.7	1.6	2.6
A_3 Selection 51	1.2	1.3	1.2	1.2	1.3	1.3
A_4 Selection 46	1.5	1.2	1.3	1.2	1.1	1.2
Means	2.3	1.4		3.0	1.5	
LSD: A factor	5% = 0.8; 1% = 1.1			5% = 0.4; 1% = 0.5		
B factor	5% = 0.5; 1% = 0.7			5% = 0.2; 1% = 0.3		
AB interaction				5% = 0.5; 1% = 0.7		

* 1 = no symptoms; 5 = severe symptoms.

Table 4. Mean zinc concentration of seed (p.p.m.) (1974–75 season)

	A_0 Kerman	A_1 Gallaroy	A_2 Selection 39	A_3 Selection 51	A_4 Selection 46	Means
B_0 nil zinc	18.25	16.50	18.00	24.25	23.50	20.10
B_1 with zinc	20.00	19.50	23.00	26.50	26.75	23.15
Means ..	19.12	18.00	20.50	25.37	25.12	

LSD: A factor— 5% = 1.19; 1% = 1.60
B factor— 5% = 0.75; 1% = 1.01

The inter-relationships between cultivars, zinc deficiency ratings and yield responses are shown in figure 1. Three cultivars gave significant yield increases with reduced zinc deficiency symptoms, while the other two cultivars gave yield increases which were not significant. Yield and zinc deficiency ratings were highly negatively correlated ($r = -0.71^{**}$).

4. Discussion

The available zinc levels in the soil of the experimental areas ranged from 0.9 to 2.1 ppm. These levels would not normally be considered low enough to induce severe zinc deficiency in plants. Although there were significant differences between varieties, foliar symptoms of zinc deficiency were severe in untreated plots of the cultivars Kerman, Gallaroy and Selection 39.

The large reduction in these symptoms in the plots sprayed with zinc showed that the plants in the untreated plots did suffer from zinc deficiency. Likewise the yield response to foliar zinc sprays of up to 86% in the same cultivars confirms the existence of zinc deficiency in the unsprayed plots.

The seed zinc concentration data show that Selection 51 and Selection 46 after spraying with zinc were able to accumulate additional zinc in the seed in quantities similar to those accumulated by the other cultivars. It appears, therefore, that even these cultivars suffered some zinc deficiency and this is confirmed by the presence of traces of foliar deficiency symptoms. As the cultivars Selection 51 and Selection 46 did not show similar yield responses to the other cultivars, and as they accumulated greater amounts of zinc in their seeds, we consider that they are more efficient at extracting zinc from the soil than are the other cultivars.

In view of the levels of available zinc in the soil, it is probable that some factor was limiting zinc uptake. This factor could be a high concentration of soil phosphorus, as suggested by Pauli, Roscoe and Moser (1968), Hudson and Cradock (1953), and Anon (1973). If data for seed phosphorus concentrations (and hence seed phosphorus-seed zinc ratios) could be obtained in future work, the data in this paper could well support the hypothesis that high soil phosphorus concentrations limit zinc uptake.

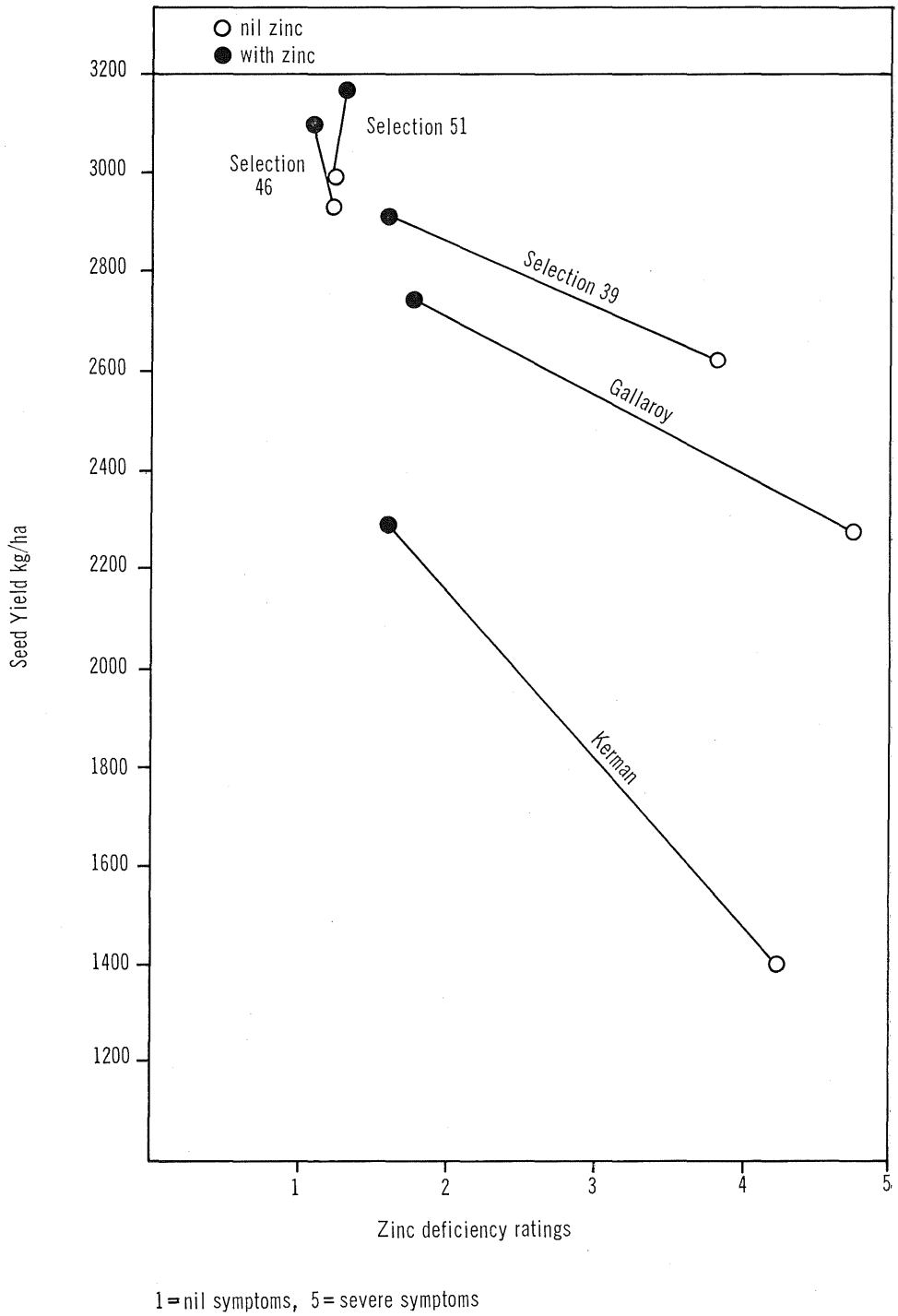

Figure 1. Inter-relationships between cultivars, zinc deficiency ratings and yield responses.

We have shown that a significant negative correlation exists between zinc deficiency ratings and yield. This could allow the use of a scale of ratings in the early stages of growth to assess the quantity of zinc spray which should be applied to navy beans. Appropriate early treatment of plants showing deficiency symptoms could reduce the effects of zinc deficiency and enhance yields. Where soils are known to be zinc-deficient and low in phosphorus, routine applications of zinc to the soil may be beneficial. If treatments are delayed until symptoms appear, potential yields may be limited.

Further work is needed on the relative efficiencies of foliar spray and soil applications of zinc.

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The authors are officers of the Queensland Department of Primary Industries. Mr Brouwer is stationed at Seed Research of Standards Branch, Indooroopilly, Q. 4068, and Messrs Stevens and Fletcher were Agriculture Branch officers stationed at Warwick, Q. 4370.