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Diagnosis and alleviation of boron deficiency causing flower and pod abortion in chickpea (*Cicer arietinum* L.) in Nepal

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Abstract

Symptoms of flower abortion and failure of pod set in chickpea in Chitwan, Nawalparasi and Makwanpur districts of Nepal suggested a nutrient disorder as a prime cause of the problem Thus, a diagnostic nutrient trial with a susceptible chickpea variety, Kalika, was conducted in the 1994/95 season Boron deficiency was established as the dominant nutritional problem causing flower and pod abortion No pods or grains were formed in the absence of applied B However, there was also a significant grain yield response to Mo In the following season, a factorial combination of different rates of B and Mo was tested Responses were less marked in this trial than previously, with no significant response to Mo application Application of 0 5 kg B ha^{-1} was found to optimally correct the syndrome It is suggested that B-deficiency may be a major factor limiting yields of grain legumes in Nepal, this is currently being assessed

Introduction

Chickpea (*Cicer arietinum* L) is the third most important legume of Nepal It is mainly grown in the Terai and inner Terai regions of the country but varieties other than Dhanush do not perform well in the soils of Chitwan, Nawalparasi and Makwanpur districts Flower abortion and consequent failure of pod set in large seeded varieties of chickpea are prevalent as a major constraint to production in these areas Although these symptoms coincide with those of Botrytis gray mold (*Botrytis cinerea*) disease which is endemic in the region (Karki et al , 1993), the flower abortion and pod set problem persists even when Botrytis gray mold (BGM) cannot be detected But affected plants show symptoms similar to those caused by boron deficiency. Abnormal plants are characterized by death of the terminal bud, increased lateral branching and progressive reduction in the size of the younger leaves, so called 'little leaves' Similar symptoms have been described in B- deficient cereals (Gupta, 1979) and *Pisum sativum* (Piper, 1940)

Boron deficiency has also been reported from northern Bihar state of India, which is adjacent to the Terai region of Nepal, and susceptible varieties of chickpea and pigeonpea have been reported to respond to application of 1 5 and 2 5 kg B ha^{-1} on a B-deficient soil (Singh et al , 1991)

Therefore, in order to precisely diagnose the problem and then determine how best to alleviate it, two field experiments were conducted at the research station of the Grain Legume Research Program (GLRP), Rampur during 1994/95 and 1995/96 growing seasons

Materials and methods

The soils of the two experimental sites are classified as 'Dystochrepts' according to the USDA Soil Taxonomy

Diagnostic trial

Soil samples were collected from the experimental site before planting of the first experiment and were analyzed in the Soils and Agroclimatology Division (SACD) at ICRISAT Asia Center (IAC). The top 15 cm soil layer had pH (1:2 H_2O) 6.2; available P (Olsen) 15 mg kg^{-1} soil; ammonium acetate (NH_4OAc) – extractable K 26 mg kg^{-1} soil; NH_4OAc – extractable Ca 301 mg kg^{-1} soil; NH_4OAc – extractable Mg 34 mg kg^{-1} soil; $CaCl_2$ – extractable SO_4-S 21 mg kg^{-1} soil; cation exchange capacity (CEC) 6.7 cmol (+) kg^{-1}; organic carbon (OC) 9.5 g kg^{-1}; Diethylene triamine penta acetic acid (DTPA) – extractable Fe, Mn, Cu and Zn at 31, 2.2, 0.56 and 0.22 mg kg^{-1} soil respectively; and hot water soluble (hws) (Gupta, 1993) B 0.2 mg kg^{-1} soil. Sand, silt and clay contents were 660, 220, and 120 g kg^{-1} soil, respectively. The first experiment conducted for diagnostic purposes was a subtractive arrangement of treatments in a randomised complete block (RCB) design replicated four times. The nine treatments were zero control (no nutrients added), complete or adequate supply of all nutrients (kg ha^{-1}: 25 P, 50 K, 20 S, 0.5 B, 2.5 Zn, 0.15 Mo, 2.5 Cu, 2.5 Mn and 2.5 Fe), complete minus B, complete minus Zn, complete minus Mo, complete minus Fe, complete minus (Cu+Mn), complete minus (K+S), complete plus lime (1200 kg ha^{-1} as fine powdered $CaCO_3$). The various nutrients were supplied through different sources as follows: Ca $(H_2PO_4).H_2O$, KCl, Na_2SO_4, H_3BO_3, $ZnCl_2$, $Na_2MoO_4.H_2O$, $CuCl_2.2H_2O$, $MnCl_2.4H_2O$, $FeC_6H_5O_7.5H_2O$.

At the experimental site, the field was ploughed three times with a disc harrow and levelled with a wooden plank drawn by a tractor. The individual plot size was 1.8 × 2.1 m. Lime was applied 4 days before sowing and all other nutrient elements were mixed thoroughly in polythene bags and applied by broadcasting and then mixing into the top 10 cm of soil with a spade one day before sowing. Kalika variety was sown in opened furrows on 26 November 1994 at a rate of 2–3 seeds $hill^{-1}$ at 30 × 15 cm spacing. Plants were first thinned to 2 plants $hill^{-1}$ at 17 days after sowing (DAS) and then to 1 plant $hill^{-1}$ at 29 DAS. The crop was manually weeded at 26 DAS. At 131 DAS, 0.72 m^2 of net harvest area was sampled for data collection.

Rate of application trial

After detecting B deficiency as a dominant nutritional cause of the problem, followed by Mo deficiency, in the first experiment, another experiment with four levels of B (0, 0.5, 1.0 and 3.0 kg ha^{-1}) as boric acid and three levels of Mo (0, 0.15 and 0.3 kg ha^{-1}) as sodium molybdate was conducted to establish optimum rates of application to alleviate the problem. The experiment was conducted adjacent (about 3 m away) to the site of the 1994/95 experiment. A factorial arrangement of treatments in RCB design, replicated three times, was used. The individual plot size was 3 × 3.6 m. Boric acid and sodium molybdate were mixed with dry soil and broadcast in respective plots followed by broadcasting of triple superphosphate (17.6 kg P ha^{-1}) and muriate of potash (16.6 kg K ha^{-1}). The fertilizers were then mixed into the top 10 cm of soil. Kalika variety was sown on 14 November, 1995 at 2 seeds $hill^{-1}$ at 30 × 15 cm spacing. Plants were thinned to 1 plant $hill^{-1}$ at 24 DAS. The crop was weeded manually at 21 and 57 DAS. Endosulphan was sprayed at 105 and 126 DAS for control of pod borer (*Helicoverpa armigera*). At 146 DAS, 6.48 m^2 of net harvest area was sampled for data collection.

In both the experiments, there was sufficient moisture in the soil as a result of residual soil water from the preceding rainy (monsoon) season and precipitation in the form of light winter rain and dew to ensure that crops did not suffer from drought stress during the crop growth period.

Results

In treatments omitting B, in both experiments, some plants showed symptoms of 'little leaf' from about 30 DAS, which persisted until crop maturity. Flowering occurred at around 80 DAS. There were many dead flowers (31 $plant^{-1}$) in the absence of applied B, but only 2 dead flowers $plant^{-1}$ resulted when 0.5 kg B ha^{-1} was applied (Table 1). When no nutrients (zero control) were applied only 15 dead flowers $plant^{-1}$ resulted. In the second experiment, application of 0.5 kg B ha^{-1} resulted in the lowest number of dead flowers (8 $plant^{-1}$) which is significantly lower than in the control (23 $plant^{-1}$) (Table 2). Application of the highest level of B, at 3.0 kg ha^{-1}, caused a significantly higher number of dead flowers compared to the application of 0.5 kg B ha^{-1} (Table 2). At the lower level of Mo (0.15 kg ha^{-1}), application of 0.5 kg B ha^{-1} resulted in 42% less flower drop than at the highest level of Mo (0.3 kg ha^{-1}). At the same level of Mo (0.15 kg ha^{-1}), application of 3.0 kg B ha^{-1} resulted in 72% more flower drop than 0.5 kg B ha^{-1}. At the highest level of Mo (0.3 kg ha^{-1}), 1.0 kg B ha^{-1} resulted in 30% less flower drop than 0.5 kg B ha^{-1}, but there was

Table 1. Effect of nutrient treatments on flower drop (at 111 DAS), total and filled pods $plant^{-1}$ and pod and grain yield of Kalika variety of chickpea at harvest, Grain Legume Research Program (GLRP), Rampur, Nepal, 1994/95.

Treatments	Dead flowers $plant^{-1}$ [a]	Total pods $plant^{-1}$ [b]	Filled pods $plant^{-1}$ [b]	Pod yield ($kg\ ha^{-1}$)	Grain yield ($kg\ ha^{-1}$)
Zero control (No nutrients applied)	15	1	0	29	7.1
Complete (P,K,S,B,Zn,Mo,Cu,Mn and Fe)	2	13	6	462	298
Complete -B	31	0	0	0.0	0.0
Complete -Zn	2	14	6	517	335
Complete -Mo	2	7	3	263	177
Complete -Fe	2	10	5	433	288
Complete - (Cu+Mn)	1	14	6	568	380
Complete - (K+S)	2	10	5	398	271
Complete + Lime	1	13	6	502	332
CV (%)	23.0	12.0	18.6	12.0	12.0
LSD (0.05)	2.6	1.5	1.1	23.9	15.7

[a] Mean of 5 plants and 4 replications
[b] Mean of 16 plants and 4 replications.

no significant difference in response between 0.5 and 3.0 kg B ha^{-1}.

No indication of BGM was observed in either experiment. When flowering began, in March of each year, minimum temperatures remained above 10° C. Thus, neither BGM nor low temperature appeared to be factors contributing to floral abortion.

In first experiment, because of the complete flower abortion no pods or grains formed in any plant when B was omitted from the complete treatment (Table 1). Omission of Mo from the complete nutrient treatment also caused significant reductions in total pods (46%), filled pods $plant^{-1}$ (50%), and in pod (43%) and in grain yields (40%). Addition of lime did not significantly increase grain yield of Kalika.

In the second experiment, application of 0.5 kg B ha^{-1} resulted in the formation of 17 filled pods $plant^{-1}$ which was significantly higher than in the control treatment (4 filled pods $plant^{-1}$) but similar to values at higher levels of B (Table 2). Maximum grain yield was obtained at the 0.5 kg B ha^{-1} treatment and this was significantly higher than in the control treatment (Table 2). The differences in grain yield response between 0.5 and 1.0 and 0.5 and 3.0 kg B ha^{-1} were not significant (Table 2). The response of any parameter to Mo was not significant in this experiment (Table 2).

Discussion

Soil properties indicate that the soil is acidic and deficient in secondary and micronutrients. The critical levels proposed are as follows: for NH_4OAc - extractable K, 50 mg kg^{-1} soil (Jackson, 1967), NH_4OAc – extractable Ca and Mg 1.5 and 1.0 cmol(+) kg^{-1} soil (Rao, 1993); hws B in acidic soil, 0.4 mg kg^{-1} soil and; DTPA – extractable Zn, Cu and Mn 0.6, 0.2 and 2.0 mg kg^{-1} soil, respectively (Gupta, 1993). Thus, possible deficiencies of K, Ca, Mg, Zn and B are indicated. A complex problem of primary, secondary and micronutrient deficiencies was also recognised in the soils of Chitwan valley by Khatri-Chhetri (1982). These deficiencies coupled with coarse texture, low pH and low organic matter content have contributed to this complex nutritional problem. The present study shows that deficiencies of B and to a lesser extent Mo, are the primary micro nutrient factors responsible for yield loss in chickpea. Phetchawee and Ratanarat (1989) also noted the severity of B deficiency mainly in coarse textured soils containing high sand fraction and low organic matter. Agarwala and Sharma (1979) also observed that B deficiency results in a marked decrease in the number of flowers and that the flowers of B-deficient chickpea plants lack pigmentation and fail to fruit, causing reductions in pod and grain yield. However, B applied at 3 kg ha^{-1} also increased flower drop in the present study. Sinha and Chatterjee (1994) have

Table 2. Effect of different levels of B and Mo on a) dead flowers per plant b) filled pods per plant and c) grain yield (kg ha^{-1}) of Kalika variety of chickpea at 124 DAS, GLRP Rampur, 1995/96.

Level of B (kg ha^{-1})	Level of Mo (kg ha^{-1}) 0	0.15	0.3	Mean
Dead flowers $plant^{-1}$				
0	23.0	23.3	23.7	23.3
0.5	8.0	8.3	14.3	10.2
1.0	11.3	9.3	10.0	10.2
3.0	13.0	14.3	12.0	13.2
Mean	13.9	13.8	15.0	
Treatment	** LSD = 3.7 dead flower $plant^{-1}$			
B	** LSD = 1.5 dead flower $plant^{-1}$			
Mo	NS			
B × Mo	** LSD = 2.6 dead flower $plant^{-1}$			
Filled pods $plant^{-1}$				
0	4.0	4.0	5.3	4.4
0.5	17.0	20.7	18.7	18.6
1.0	17.3	23.0	19.0	19.7
3.0	20.0	20.7	15.0	18.5
Mean	14.5	17.0	14.5	
Treatment	** LSD = 6.1 dead flower $plant^{-1}$			
B	** LSD = 2.53 dead flower $plant^{-1}$			
Mo	NS			
B × Mo	NS			
Grain yield (kg ha^{-1})				
0	208	188	248	215
0.5	834	833	796	820
1.0	815	952	814	860
3.0	871	896	770	846
Mean	682	717	657	
Treatment	** LSD = 218 kg ha^{-1}			
B	** LSD = 89 kg ha^{-1}			
Mo	NS			
B × Mo	NS			

NS not significantly different $p<0.05$
** Significantly different at $p<0.05$

also reported the adverse effect of the excess supply of B on the inflorescence in pearl millet.

When a complete nutrient application minus B was applied to chickpea, as in the first experiment, the severity of B deficienc¸ appeared more acute than when no other nutrients were applied at all (zero control). This may have been a result of dilution effects of other added nutrients on B uptake from an already low level of availability in the soil. Thus B requirement is likely to vary depending on supply and availability of other nutrient elements.

Boron responses also differed between years, being more severe in 1994/95. This may have been due to differences in soil availability of B between the sites of the two experiments, although they were adjacent to each other. Only composite soil samples from the general area were collected in 1994 and analyzed for B. Another reason may be differing weather patterns between years, affecting transpiration rates and therefore B uptake and transport to reproductive tissues. It was also noted that maximum grain yields in both seasons were relatively low considering yield potential of chickpea for the region. Thus factors other than nutrients may have been limiting yields and thereby interacting with B response. Nevertheless whether other yield limitations were operating, the results clearly indicate a severe B limitation in both years and a Mo deficiency in the first year.

It is well established that Mo deficiency increases in likelihood as soil pH declines (Evans et al., 1951). At the site of this study pH was only marginally acid and microsite differences in soil pH may have shifted the balance between Mo deficiency and sufficiency, between 1994/95 and 1995/96 respectively. However, the lack of response to lime application in 1994/95 suggested that the acid soil syndrome (including Mo deficiency as a factor) was not a major limitation. Another possible reason for the difference in Mo response between years may have been competitive effects on Mo availability or uptake of some of the additional nutrient ions added in 1994/95 but not 1995/96. Alternatively, seed Mo levels for the 1995/96 sowing may have been higher than the previous year, and sufficient to supply crop needs despite low soil Mo. Further diagnosis of incidence of Mo deficiency in chickpea in this region is warranted.

The present results suggest that basal soil application of 0.5 kg B ha^{-1} is appropriate to correct the severe B deficiency problem at this location. However, caution is required in avoiding an excessive dose as present results suggest that 3 kg B ha^{-1} may increase flower death in chickpea. Studies are in progress to determine how widespread this B deficiency problem in chickpea is in the region, particularly in Nawalparasi, Chitwan and Makwan districts. Simple treatments with and without B application are being imposed in small plots in farmers fields, along with soil analyses and symptom observations. Similarly, extent of B deficiency is being tested in other grain legumes grown in the region, such as pigeonpea, lentil and groundnut.

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References

Agarwala S C and Sharma C P 1979 Recognising Micronutrient Disorders of Crop Plants on the Basis of Visible Symptoms and Plant Analysis. Prem Printing Press, Lucknow, India. 51 p

Evans H J, Purvis E R and Bear F E 1951 Effect of soil reaction on availability of molybdenum Soil Sci. 71, 117 124.

Gupta U C 1979 Boron nutrition of crops. Adv Agron 31, 273 307.

Gupta V K 1993 Soil analysis for available micronutrients. *In* Methods of Analysis of Soil, Plant, Water and Fertilizer. Ed H L S Tandon, pp 36 48. Fertilizer Development and Consultation Organisation, New Delhi, India.

Jackson M L 1967 Potassium determinations for soils. *In* Soil Chemical Analysis pp 111 113 Prentice-Hall of India, New Delhi, India

Karki P B, Joshi S, Chaudhary G and Chaudary R N 1993 Studies on Botrytis Gray Mold of chickpea in Nepal *In* Recent Advances in Research on Botrytis Gray Mold of Chickpea Summary Proceedings of the Second Work Group to discuss Collaborative research on Botrytis Gray Mold of Chickpea, Rampur, Nepal, 14–17 March 1993 Ed M P Haware, pp 11 13 ICRISAT, Patancheru, India

Khatri-Chhetri T B 1982 Assessment of soil test procedures for available boron and zinc in the soil of Chitwan valley, Nepal. Ph D thesis, University of Wisconsin, Madison, U S A.

Phetchawee S and Ratanarat S 1989 Surveys on boron deficiency of groundnut in farmers fields in central and eastern Thailand in 1987 *In* Proceedings of the 7th Thailand National Groundnut Meeting, Pattaya, Chonburi, 16-18 Mar, 1988 Ed A Patanothai, pp 373 376 Khon Kaen University, Thailand

Piper C S 1940 The symptoms and diagnosis of minor-element deficiencies in agricultural and horticultural crops Empire J of Exp Agric 8, 85 96

Singh A P, Sakal R, Sinha R B and Bhogal N S 1991 Relative response of selected chickpea and pigeonpea cultivars to boron application Ann Agric Res 12, 20 25

Sinha P and Chatterjee C 1994 Influence of boron on yield and grain quality of pearl millet Indian J. Agric Sci 64, 836–840

Subba Rao A 1993 Analysis of soils for available major nutrients *In* Methods of Analysis of Soil, Plant, Water and Fertilizer Ed H L S Tandon, pp 13–35 Fertilizer Development and Consultation Organisation, New Delhi, India

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