

Diagnosing nutrient limitations to lentil and chickpea in acid soils of Bangladesh

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Abstract

Lentil and chickpea are dietary staple crops in Bangladesh but their local production has been markedly declining in recent decades, mainly due to competition with irrigated cereals. However, in northern Bangladesh, an additional problem to their cultivation is acid surface soil conditions, potentially causing deficiencies of molybdenum (Mo) and boron (B), and toxicities of aluminium (Al), manganese (Mn) or hydrogen ion (H⁺). In an attempt to rehabilitate lentil and chickpea in northern Bangladesh on-farm trials were conducted to determine the response of these crops to Mo, B, lime and *Rhizobium* inoculation. Despite earlier reports of widespread B deficiency in the region a response to B was only found in chickpea. Responses to Mo and *Rhizobium*, applied through seed priming, were found. There were responses to lime even after B, Mo, and *Rhizobium* had been applied, suggesting Al toxicity. Recommendations for fertilizer requirement, to fit into an overall integrated crop management package for lentil and chickpea, were modified accordingly.

Key words

Pulses, boron, molybdenum, *Rhizobium*, aluminium, on-farm trials.

Introduction

In the grey terrace soils of the High Barind Tract (HBT) of Bangladesh (Brammer 1996), chickpea (*Cicer arietinum* L.) is cultivated on residual soil moisture following the rainy season rice crop harvested in November (Musa et al. 2001). However, some surface soils are acid (pH <5.5) and here it is necessary to apply Mo and *Rhizobium* inoculum to ensure adequate vegetative growth of chickpea (Johansen et al. 2007a). These additives are most conveniently and effectively applied during the seed priming process, as seed priming is necessary to ensure adequate emergence in rapidly drying seedbeds (Musa et al. 2001; Johansen et al. 2007a). In a project to promote cultivation of lentil (*Lens culinaris* Medikus) and chickpea in the non-calcareous brown floodplain soils to the north of the HBT (Brammer 1996), in the extreme north-west of Bangladesh, it was assumed there would be similar requirements for Mo and *Rhizobium* as surface soils are also acid here. Additionally, widespread deficiencies of B have been found for chickpea and other crops in this region (Ahmed and Hossain 1997), and application of phosphorus (P) fertilizer is required for most field crops in this region (Karim et al. 1989).

In assembling integrated crop management (ICM) packages for lentil and chickpea to demonstrate on farmers fields, applications of P, B, Mo and *Rhizobium* were included, based on assumptions from prior studies, along with the required insect pest, disease and weed management strategies and other agronomic recommendations (Sarker et al. 2004; Johansen et al. 2007a, 2008). While beginning a series of on-farm demonstrations including required inputs, it was necessary to validate the extent to which each of these inputs are indeed required, such that economic optimum ICM packages could be formulated. Therefore a series of on-farm trials for lentil and chickpea were conducted, evaluating the requirement for B, Mo and *Rhizobium*, and assessing if there is any additional requirement for lime to alleviate soil acidity.

Methods

Experiments with lentil and chickpea were conducted in farmers' fields in the rainy seasons of 2006-07 to 2008-09. However, the lentil experiment in 2006-07 and chickpea experiment in 2006-07 had to be abandoned primarily due to excess soil moisture conditions damaging crop establishment. Locations and pH of the 0-15 cm soil profile of sites harvested are given in Table 1.

Table 1. Locations, surface soil pH_{H2O} and sowing and harvest dates of nutrient experiments with lentil and chickpea in north-western Bangladesh, 2006-07 to 2008-09 seasons.

Season	Crop	Location			Soil pH	Sowing date	Harvest date
		District	Upazila	Village			
2006-07	Chickpea	Thakurgaon	Thak. Sadar	Nargun	4.7-5.1	19 Nov 06	26 Mar 07
2007-08	Lentil	Thakurgaon	Thak. Sadar	Kohorpara	6.2	06 Nov 07	13 Mar 08
2008-09	Chickpea	Panchagarh	Atwari	Shah Para	5.6-5.7	06 Dec 08	13 Apr 09
2008-09	Lentil	Thakurgaon	Thak. Sadar	Sasla Pjala	5.5-5.6	10 Nov 08	12-13 Mar 09

Experiments were laid out in randomized block design with 4 or 5 treatments in 4 replications (blocks). Replications were dispersed around a village in 2008-09 but were in the same or adjacent fields in earlier seasons. Treatments comprised a control plot where 1 kg/ha B as boric acid, 1.5 g Na₂MoO₄·2H₂O/L priming water and 4 g *Rhizobium* inoculum/L priming water (but 40g/L in 2008-09) were added, and plots either without B, Mo or *Rhizobium* (although –Mo and –*Rhizobium* treatments were combined in 2006-07), and a treatment of control + 1.5 t/ha lime (a local calcium magnesium carbonate named “dolachun”). One kg seed was added per L priming water in which the sodium molybdate was dissolved and the peat-based *Rhizobium* inoculum suspended. Priming was conducted for 8-10 hr overnight prior to sowing, during which time all of the water was imbibed by the seeds (Johansen et al. 2007a). Triple superphosphate (TSP) was applied to all plots at 100 kg/ha as a basal dressing. Lentil variety BARI masur 4 was sown at the seed rate of 34 kg/ha and chickpea variety BARI chola 5 at the seed rate of 37.5 kg/ha.

Plot size was 5 x 5 m and plots were cultivated with a rotary power tiller, B and TSP fertilizers, lime and seed hand broadcast, and the plots then raked to incorporate seed and fertilizer. Crops were grown rainfed, mainly on residual soil moisture from the preceding rainy season and the crop growing period is given in Table 1. Lentil plots were hand weeded during 15-35 days after sowing (DAS) and chickpea plots at 45-50 DAS. Stemphylium blight of lentil was managed by spraying Rovral-50[®] wp @ 0.2% at 45 DAS. Chickpea was protected from Botrytis grey mould (BGM, caused by *Botrytis cinerea*) by spraying Bavistin[®] at 1 kg/ha at 45-50 DAS and from pod borer (*Helicoverpa armigera*) by spraying Karate[®] @ 1 L/ha in 500 L water at 65-70 DAS. At harvest, 5 x 1 m² quadrats were cut from each plot and the grain weight measured after threshing.

Results and Discussion

For lentil in 2006-07, yield in the control plot was well above the national average yield of about 0.8 t/ha. There was no effect of omitting B fertilizer but yield was significantly reduced when either Mo or *Rhizobium* were omitted (Table 2). There was an indication of a lime response above the control but this was not significant. In 2008-09, however, growth of lentil was generally poor with considerable intra- and inter-plot variability (i.e. between plots with the same treatment), the main yield constraints being excess soil moisture at sowing and seedling collar rot caused by *Sclerotium rolfsii*. No significant differences between treatments were recorded although the control plot appeared lowest yielding and that with lime added highest yielding (Table 2).

For chickpea in 2006-07, growth and grain yield in the control plot was above the national average (0.75 t/ha) and there was a significant reduction in yield when either B, Mo or *Rhizobium* were omitted (Table 2). Yield with lime added was significantly higher than in the control. In 2008-09, yield of chickpea was generally low and variable, for the same reasons as mentioned for lentil in 2008-09, and there was no significant difference between treatments although the limed plot had the highest yield (Table 2).

Table 2. Grain yield (kg/ha) response of lentil and chickpea to nutrient treatment in acid soils of northern Bangladesh during 2006-07 to 2008-09 seasons.

Treatment	Lentil		Chickpea	
	2007-08	2008-09	2006-07	2008-09
Control	1,700	439	1,010	409
Minus B	1,663	737	673	535
Minus Mo	1,425	745	702	455
Minus <i>Rhizobium</i>	1,250	707		425
Plus lime	1,813	946	1,284	923
Probability	<0.001	0.24	<0.001	0.50
SE	78		44	

From prior knowledge of the likelihood of acid soil problems limiting lentil and chickpea in northern Bangladesh, this study attempted to quantify their effects in farmers' fields. However, it became apparent that constraints other than nutritional were major determinants of grain yield. A field survey of the target region in the 2006-07 season concluded that the major constraints for lentil were excess soil moisture at establishment reducing emergence and nodulation, Stemphylium blight and weeds, and for chickpea BGM, pod borer, collar rot and excess soil moisture at establishment (Johansen *et al.* 2007b). Acid soil factors and nutritional constraints were ranked below these constraints. In 2008-09, the major constraints probably overrode the nutritional ones, masking their expression (Table 2). Therefore, a flexible approach in trying to managing nutritional constraints is warranted, dependent on the likely severity of non-nutritional constraints.

A B response was only recorded for chickpea in one season (Table 2). Distinct B deficiency symptoms for lentil and chickpea ("little leaf" and yellowing in shoot apices) only occur sporadically between fields, and are probably related to soil organic matter status (Srivastava *et al.* 2005) which can be quite variable in northern Bangladesh. The major requirement for B is during yield formation, and B can be effectively applied as a foliar spray to the growing crop. It is therefore proposed that application of B be dependent on appearance of symptoms of B deficiency, and then foliar application of B can be implemented, as opposed to applying B fertilizer to the soil at sowing.

When crop growth potential is high, there is a need to apply Mo (if lime is not applied) and *Rhizobium* to maximize yield (Table 2), but there is no scope for delayed application as in the case of B. There is therefore a need for a universal recommendation to apply Mo and *Rhizobium* for soils where lentil and chickpea are not normally grown, until Mo residual value and soil *Rhizobium* population increases. The presence of collar rot suggests a need for seed application of a fungicide, which could interfere with effectiveness of *Rhizobium* inoculant and the fungicide may be diluted with seed priming. Unlike the HBT, most soils in northern Bangladesh remain sufficiently moist, if not excessively wet, which does not warrant use of seed priming. However, the most efficient way to add Mo for chickpea and lentil is through seed priming. Further experimentation is required, and is now underway, to find effective ways of adding Mo, *Rhizobium* and fungicide to seeds, with or without seed priming.

An additional response when lime is added to the control treatment could indicate insufficient addition of Mo or, more likely, an effect of lime in ameliorating toxicities of Al, Mn or H⁺. Aluminium saturation levels are 29-71 % in Thakurgaon Sadar and 37-54 % in upazilas adjacent to Atwari Upazila in Panchagarh District (Bodruzzaman 2009). Aluminium saturation levels >40 % are usually toxic for legumes (Kamprath 1978). We do not have data on available Mn levels in these soils. Low pH levels *per se* can inhibit nodulation and symbiotic nitrogen fixation but we remain unsure of the extent to which this is occurring in this situation. The breakeven point for adding 1.5 t/ha lime to lentil or chickpea is an additional yield of about 100 kg/ha, although farmers usually require benefit:cost ratio >2 on marginal return before adopting an additional input. Largest marginal returns appear to be when overall yield is low, in 2008-09 (Table 2), but these values are not significant due to variability caused by other constraints.

Conclusion

In adjusting ICM packages for lentil and chickpea in the target region it is suggested that B application can be need based, through foliar application after appearance of the distinct B deficiency symptoms. For areas where lentil and chickpea are not regularly grown, a basal application of Mo + *Rhizobium* appears essential. However, due to the commonly wet surface soils, and thus no need for seed priming, further experimentation is required to find an effective way of applying Mo, *Rhizobium* and fungicide to seed. Consideration of applying lime would need to be deferred until more reliable means of managing the major constraints – excess soil moisture, foliar diseases, pod borer – are established.

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