Triple superphosphate placement affects early growth of chickpea

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Abstract

Fertilizer placement with and close to the seed may have inhibitory effects on early growth of plants. In a pot study, chickpea (*Cicer arietinum* L.) root growth and nodulation was assessed by placing triple superphosphate (TSP) with seed (0) and 2 or 5 cm directly below the seed and in a control (TSP mixed thoroughly with the top 10 cm of soil) using a sand and a clay loam soil. Phosphorus fertilizer with and close to the seed produced necrotic symptoms in the lower leaves and reduced total root length, root surface area and nodule dry weight in sand. In clay loam there was no specific response of banding TSP, but most measured parameters were lower in the 0 and 2 cm treatments. TSP banding with and close to (<5 cm) the seed inhibited early growth of chickpea, especially in sandy soil, but less so in clay loam soil.

Keywords

Banding, fertilizer placement, minimum tillage, phosphorus, rice-based cropping system, toxicity

Introduction

In Bangladesh, chickpea is grown under rainfed conditions relying mostly on residual soil moisture after rainy season rice (*t. aman*). In the High Barind Tract (HBT) of northwest Bangladesh, power tillers have increasingly replaced bullocks for tillage, and can rapidly cover a large area for timely sowing of chickpea. However, the shallow and excessive cultivation by the rotary power tiller hastens evaporation of top soil moisture and makes chickpea more prone to terminal drought. To overcome these constraints, power tiller mounted minimum tillage planters (strip till) are under development.

Reduced fertilizer use efficiency is a common phenomenon in dry topsoil, particularly for phosphorus (P) fertilizer. Minimum tillage planters place seed and P fertilizer, triple superphosphate (TSP), together in a narrow slot of moist soil aiming to increase fertilizer use efficiency and nutrient uptake in the early growth of chickpea. However, there is a concern that TSP placed close to seed will inhibit emergence and establishment of chickpea seed, as reported previously for phosphorus fertilizers (MAP, DAP) in other species (Moody *et al.* 1995; Zhang and Rengel 1999). Zhang and Rengel (1999, 2000) reported in wheat that increased NH_4^+ and P concentration close to the developing seed may suppress early growth including root growth. Fertilizer toxicity in wheat with DAP was avoided if it was banded away from the seed (Jarvis and Bolland 1991; Zhang and Rengel 2000). In a preliminary glasshouse study, TSP placed with the seed reduced root length significantly in a sandy soil; in clay soil, P reduced root length in 12 days-old chickpea. In this study, it was hypothesised that early growth depression due to seed-placed TSP would be alleviated by banding it away from the seed.

Materials and Methods

Plants were grown in PVC columns of 30 cm height and 15 cm diameter containing 7 kg each of sand (yellow sand; pH_{CaCl2} 4.97) or clay loam soil (topsoil from Merredin; pH_{CaCl2} 6.63). Basal salts of nutrients were mixed as described in Bell *et al.* (1989) in sieved (4 mm mesh) soil. From the bottom, 18.5 cm of each column was filled with air dried soil. A further 10 cm was filled up after amendment with basal salts and TSP according to treatments.

Treatments: Granular TSP required per seed (0.15 g) was calculated based on the recommended broadcast dose for chickpea (100 kg/ha, i.e. 20 kg P/ha) in the HBT and the row spacing (40 cm). The placement distances were 0 (TSP mixed with a 2 cm layer of soil around seeds), 2 and 5 cm directly below the seed where TSP was mixed with a 2 cm layer of soil. A control treatment was included in which TSP was thoroughly mixed in the top 10 cm of soil to simulate broadcasting and ploughing in the field. Seed was placed 3 cm below the surface. Each treatment had three replications.

Growing and harvesting of plants: Rhizobium (Nodular, Group-N) suspension (@ 100 g/L water) was applied @ 1 mL/seed under the seed just before sowing. Twelve seeds of *desi* chickpea cv Genesis 836 were sown per column on 1 August 2009 and the columns kept in a glasshouse with 26/9 ^{o}C day/night temperature. Watering was done just after sowing, and every alternative day by weighing the soil to maintain water at field capacity (clay 14 % and sand 8 %). Harvesting was done at 24 days after sowing (DAS). Roots were washed under gently running water on a sieve (<0.5 mm) to prevent root loss. Nodules were counted and separated from the root and washed roots were assessed for root length and surface area using a scanner controlled by WinRhizo software (Regent Instruments, Quebec, Canada). Plant materials were dried in a forced-draft oven at 65 ^{o}C for 72 hrs and weighed.

Statistical analysis: Data were analyzed by Analysis of Variance (ANOVA) following a completely randomized design (CRD) by Statistix 8 software. Least significant difference (LSD) was used to test differences between treatment means.

Results

In sand, total root length in 0 and 2 cm treatments and root surface area in 0 cm was significantly reduced compared to 10 cm mixing treatment (Table 1). Although there was no significant difference in root and shoot dry weight, highest values were also observed in the 10 cm mixing treatment. Nodule dry weight was significantly reduced in 0 cm due to both smaller size (visual observation) and reduced number. Phosphorus toxicity symptoms (grayish white necrosis) were observed in lower leaves in 0 and 2 cm at 10 DAS; and in some plants of 5 cm and even in few plants of 10 cm mixing treatments at 13 DAS.

Table 1. Effect of triple superphosphate banding on the growth of chickpea at 24 days after treatment.

TSP placement below seed	Total root length (cm)	Root surface area (cm^2)	No. of nodules	Dry weight (mg)		
				Root	Shoot	Nodule
Sandy soil						
0	516	110	9.6	68.0	122	11.4
2 cm	513	112	9.5	68.4	119	14.2
5 cm	528	112	12.	68.5	122	16.8
10 cm mixing	571	122	11.8	74.2	135	17.0
CV	4.9	4.9	21.9	9.9	8.9	19.7
LSD (P=0.05)	49.3	10.5	ns	ns	ns	5.5
Clay soil						
0	431	88	29.3	52.2	205	7.8
2 cm	379	80	27.8	49.4	200	5.5
5 cm	462	95	27.6	53.6	209	8.3
10 cm mixing	436	91	31.3	55.8	230	6.2
CV	10.2	9.5	15.8	10.1	6.7	32.2
LSD (P=0.05)	82.1	ns	ns	ns	26.5	ns

ns- not significantly different (P < 0.05)

In clay loam soil, banding TSP with seed (0 cm banding) produced similar root, nodule and shoot growth to 10 cm mixing treatments (Table 1). Indeed, there was no effect of P fertilizer placement on root dry weight, root surface area, nodule number and dry weight. Shoot dry weight and root length were greater in 10 cm mixing treatment than 2 cm banding.

Discussion

In sand, the suppression of emergence when P was banded with the seed (0 cm) might be due to the osmotic effect of fertilizer which limits moisture uptake by the germinating seed. As P fertilizers have relatively lower salt index (SI) than nitrogen and potassium fertilizers (Mortvedt 2001), and TSP has a lower SI value than that of mono and diammonium phosphate, the final emergence was not reduced (data not shown). In field grown lupin in light textured soil, superphosphate banded with the seed reduced plant density and early growth due to high concentration of P and/or salt and the consequence of high osmotic pressure close to seed

(Jarvis and Bolland 1991). Superphosphate (Jarvis and Bolland 1991) and DAP (Zhang and Rengel 2002) toxicity happens only in the early growth stages, with symptoms generally disappearing with time and during more advanced stages of plant growth.

Toxicity symptoms in the terminal leaflets of the oldest leaf are a feature common to all salt toxicities (Greenway 1962). This might result more from the deleterious effects of excess salts within the tissues than from specific toxicity of accumulated phosphate ions (Bhatti and Loneragan 1970). Miller *et al.* (1970) suggested that DAP-related growth reduction was due to Ca deficiency caused by precipitation of Ca-P complexes.

Although there were no symptoms in plants grown in clay loam soil throughout the experimental period, decreased root length in 2 cm banding treatments (significantly less than in 10 cm mixing) might be due to an adverse effect of TSP in the root environment. This result is in accordance with Bhatti and Loneragan (1970) who found that severe depression of root growth in wheat starts before appearance of any symptom in the shoots even though their study was in siliceous sand. Just after emergence of the radical, the tender tip is inhibited in elongation when it encounters the concentrated fertilizer bands, which are not present when TSP is mixed in the top 10 cm of soil. However, after sowing, strong crusts formed on the top of every column of clay loam soil, some of which cracked. Crusting and variable cracking may have confounded the P placement effects on emergence and early growth especially in the 2 cm treatment.

Decreased root length in 0 and 2 cm banding depth especially in sand suggests that banding P fertilizer with and close to seed created toxicity. Blanchar and Caldwell (1966) found that oat roots did not grow in to a monocalcium phosphate (MCP) band. Also, Ouyang *et al*. (1998) reported that root growth stopped in the vicinity of a band containing urea and triple superphosphate (TSP). Actually, they used TSP as an ameliorating compound against NH_4^+ toxicity from urea. Trapeznikov *et al*. (2003) showed in wheat that shorter roots with more laterals grew in the nutrient-rich patch, while longer roots were observed where the same amount of nutrients (NPK compound fertilizer 11:10:11) was thoroughly mixed with the soil. They anticipated that ABA produced in the root due to increase in nutrient concentration reduced root elongation, since ABA is known to inhibit root elongation of well-watered maize seedlings (Sharp and Le Nobble 2002). Increased root length in the 5 cm banding treatment in both soils may be due to avoidance of salt toxicity and increased P fertilizer efficiency. Jarvis and Bolland (1990, 1991) found that banding superphosphate 5-8 cm below lupin seed avoids P toxicity problems.

Conclusion

From these results it is concluded that application of TSP with the seed and banding at 2 cm in sand is risky for seed emergence and early growth. In sand, a banding distance >5 cm seems necessary but it still has some suppressive effect on early growth. In clay loam soil, the recommended dose of TSP (100 kg/ha) was less toxic, with only marginal effects observed on emerged seedling growth. Thus banding of TSP directly with seed in the silty clay HBT soils in strip tillage is not likely to result in toxicity to chickpea. However, the dose of 100 kg/ha has been established for hand broadcast seed and fertilizer. Placement of TSP adjacent to the seed, as in strip tillage, may increase fertilizer use efficiency, and thus a reduced rate could meet the P needs of the crop. Our field study in a silty clay soil in the HBT in the 2008-09 season suggested that grain yield at 100 kg TSP/ha was not significantly different to that at 50 kg TSP/ha, but further confirmatory studies are required.

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