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Purbasha P Padhi
Department of Soil Science, College of Agriculture, OUAT, Bhubaneswar, Odisha, India

SK Pattanayak
HOD, Department of Soil Science College of Agriculture, OUAT, Bhubaneswar, Odisha, India

Purushottam
Department of Agronomy College of Agriculture, IGKV, Raipur, Chhattisgarh, India

Correspondence
Purbasha P Padhi
Department of Soil Science, College of Agriculture, OUAT, Bhubaneswar, Odisha, India

Effect of lime coating and molybdenum seed treatment on productivity and nutrient uptake of different pulses grown in Alfisols

Purbasha P Padhi, SK Pattanayak and Purushottam

Abstract
In order to study the effect of lime coating and molybdenum seed treatment on pulses grown in Alfisols, a field trial was conducted in the village Haripur of Khordha district during summer (2017). The experimental soil was sandy loam in texture, strongly acidic soil reactions (pH_w-4.49) with low organic carbon (4.6g/kg soil), and low status for available N, P, K, S and Mo. Each of the four crops (green gram, black gram, cowpea, horse gram) was subjected to five package of practices (POPs), namely (i) Only application of soil test dose (STD) of fertilizers without seed inoculation with *Rhizobium*, (ii) STD + seed inoculation with *Rhizobium* (R), (iii) STD + seed inoculation with *Rhizobium* (R) + seed coated with lime ($CaCO_3$) @ 12.5 mg seed^{-1} or 4 kg $CaCO_3$ for 25 kg of seed required for one hectare of land (S_L), (iv) STD + seed inoculation with *Rhizobium* (R) + molybdenum seed treatment @ 10 g sodium molybdate 25 kg^{-1} seed required for one hectare of land (Mo), (v) Adoption of all the above packages (STD+R+S_L+Mo). The POPs supported balanced nutrition of crops with all positive balance for organic carbon and available major nutrients like N, P, K and S in post-harvest soil. The POPs were capable of doubling the seed yield under problematic soil conditions like acid soils.

Keywords: Pulses, productivity, lime coating, *Rhizobium*, molybdenum, acid soil

Introduction

Promoting the cultivation of pulses can help India overcome nutrition insecurity, improve soil fertility by nitrogen fixation and provide income support to farmers. Besides, being a rich source of protein, pulses have the capacity to fix the atmospheric nitrogen and can sustain in low fertility and limited soil moisture conditions due to deep root system. It fix atmospheric N_2 ranging from 50-100 kg ha^{-1} annum^{-1}. However under Odisha condition it ranges from 25 to 55 kg ha^{-1} (Pattanayak, 2016) [14, 16, 18]. The per capita availability of pulse in Odisha is improving gradually as a consequence of increasing in cultivated area but not the productivity (508 Kg/ha) which is lesser than national average (651.2kg/ha).

Soil acidity is the major constraint for pulse production. Acidic soil reduces nodule formation and nitrogen fixation, reduces plant flavonoid secretion. More than seventy percent soil of Odisha is acidic, out of which more than 25 percent need immediate liming having pH < 5.5 (Pattanayak and Sarkar, 2016) [16]. Again *Rhizobium* starvation is common in micronutrients deficient acid soil. In acidic soils (pH <5·5) molybdenum availability decreases as anion adsorption to soil oxides increases (Reddy *et al*., 1997) [20]. It is generally accepted that legumes need more Mo than most of other plants (Mcbride, 2005) [12] due to its key involvement in the Nitrogen-fixation process. Molybdenum is required to the *Rhizobium* bacteria for proper function of nitrogenase enzyme which involved in nitrogen fixation. Again molybdenum is the cofactor for the enzyme nitrate reductase which involved in nitrogen assimilation (Hansch and Mendel, 2009) [7]. The application of molybdenum in deficient soil encouraged nitrogen fixation and nodule formation (Rahman *et al*., 2008) [19].

Liming ($CaCO_3$) is routinely used as long-term agricultural management practice to neutralize the acid produced in the soil and to overcome the problems associated with soil acidification. Most plants grow well at a pH range of 5.5–6.5 and liming is aimed to maintain the pH at this range. Earlier recommendation was application of lime at full rate 15-30 days before sowing. Then lime application @ 0.2 L.R for dicot and 0.1 L.R for monocots have been recommended for crop production. But the effect of lime is not permanent, it needs frequent application preferably mixed with organic materials (Pattanayak and Sarkar, 2016) [16].

The pure liming material ($CaCO_3$) is costly, less available and not affordable by poor farmers.

To reduce the amount of liming materials and getting almost similar effect of liming, coating of seeds of green gram with lime using gum acacia (Majhi and Pattanayak 2015) [11] and sagoo (Pati and Pattanayak 2016) [14] as stickers proved to be a better option for increasing productivity, grown in acid soils.

There is tremendous scope to increase current yield potential of pulses by enhancing the nutrient availability and better plant growth through liming, incorporation of micronutrients and biofertilizers in the production system. However selection of effective combination of package of practices is a critical step. Keeping this view in mind the present study was formulated with four pulse crops like green gram, black gram, cow pea and horse gram to access the most suitable combination of *Rhizobium*, Mo seed treatment and lime coating of seed for maximization of pulse productivity and its effect on nutrient uptake in acid soil.

Materials and Methods

The field experiment was conducted in the village Haripur of Khordha district during summer (January 2016-17). Haripur is situated at 20^0 07` 66" N latitude and 85^0 42' 81" E longitude. The soil of the experimental field comes under the soil order of Alfisols. The four crops were selected with three replicates and each consisted of five package of practices (POPs), namely (i) Only application of soil test dose (STD) of fertilizers without seed inoculation with *Rhizobium*, (ii) STD + seed inoculation with *Rhizobium* (R), (iii) STD + seed inoculation with *Rhizobium* (R) + seed coated with lime ($CaCO_3$) @ 12.5 mg $seed^{-1}$ or 4 kg $CaCO_3$ for 25 kg of seed required for one hectare of land (S_L), (iv) STD + seed inoculation with *Rhizobium* (R) + molybdenum seed treatment @ 10 g sodium molybdate 25 kg^{-1} seed required for one hectare of land (Mo), (v) Adoption of all the above packages (STD+R+S_L+Mo) with four test crops i.e. Green gram (Durga), Black gram [B-3-888 (CV.Prasad)], Cow pea [KSP-145 (Kalasa)], and Horse gram having a plot size $7m^2$. The experiment was laid out with Factorial Randomised Block Design with 5 (five) POPs, each replicated thrice. The treatments were allocated to different plots following the random number table of Gomez and Gomez (1976).

After thorough field preparation initial soil samples were taken to analyze the initial soil properties. The soil of the experimental field was sandy loam in texture with 11 percent clay and 7.0 percent sand. It was strongly acidic in reaction (pH_w 4.49) with low organic carbon (4.60 g kg^{-1}), available nitrogen (201 $kgha^{-1}$), phosphorus (7.2 $kgha^{-1}$), potassium (108 $kgha^{-1}$), Sulphur (14.5 $kgha^{-1}$), boron (0.15 mg kg^{-1}) and molybdenum (0.023 mg kg^{-1}), but zinc (0.74 mg kg^{-1}) was adequate. The CEC was 8.2 cmol(p^+) kg^{-1} soil with no limitation for exchangeable Ca^{2+} and Mg^{2+}. The base saturation percent was 58 percent. Aluminum acidity was dominating over acidity due to H^+ ions. The lime requirement was 1.2 t $CaCO_3$ ha^{-1} to raise the pH to 6.5.

Fertilizers were applied on the basis of Soil test Dose i.e. N - P_2O_5 - K_2O - $ZnSO_4$ – Borax (kg/ha) (20 - 40 - 40 – 25 - 10) from different sources like Navaratna (20-20-0-13), SSP, MOP, Borax and Zinc sulphate along with application of farmyard Manure (FYM) @ 3 t ha^{-1}.

The seeds were treated with bavistin @ 2 g kg^{-1} seed as seed treatment chemical against fungal seed borne diseases. As per treatment specificity seeds were inoculated with *Rhizobium* @ 20 g kg^{-1} seed. The inoculated seeds were again coated with lime using sagoo as sticker. The water soaked sago (Tapioca root extract) was boiled in hot water to form a jelly like sticking substance. Allowed it to cool, before adding it to the inoculated seed (since hot water will kill the *Rhizobia*). It was poured in to a container containing *Rhizobium* inoculated seeds and powdered lime. Then rotated and shaken in a manner so that lime get coated on each seed. Seeds were treated with sodium molybdate @ 10g 25kg^{-1} seed either in combinations with *Rhizobium* culture or with lime coating as per the treatment.

Yield attributes were recorded at physiological maturity stage. The seed and stover yield was recorded from net plot area of each treatment and expressed in kg ha^{-1}.

The soil samples were tested with organic carbon content, available N, P, K as per methods given by Subbiah and Asija (1956) [22]. Available S extracted by the method of Willams and Steinbergs (1959) [25] and determined by the method of Chesnin and Yien (1951) [5]. Available Mo extracted with Ammonium oxalate solution and was estimated by spectro-photometer as outlined by Dhyansingh and Chhonkar (2010) [22]. The plant samples were analyzed for N, P, K, Ca, Mg and S. The samples were analysed (except N) by taking 0.5mg materials digesting in di-acid mixture [HNO_3: $HClO_4$ (3:2)] by using standard analytical methods (Jackson 1973).Nitrogen was estimated by micro-kjeldhal method. (AOAC 1960) [1]

Results and Discussion

The present study was conducted based on confirmation of results of two sets of experiments one on Mo seed treatment @ 10 g sodium molybdate per 25 kg legume crops seeds grown in acid soil (Pattanayak *et al*., 2000, Dash *et al*., 2000) [17] and another "lime coating of green gram seeds influencing the yield, nutrient uptake and post-harvest soil properties" (Pati and Pattanayak 2016) [14]. The present experiment was on the occasion of "International Year of Pulses giving emphasis on increasing the productivity of pulse crops" the essential component of balanced diet. The four target pulse crops were green gram, black gram, cowpea and horse gram. Their productivity in the state is 476, 455, 746 and 385 kg ha^{-1} respectively against the demonstrated yield of 900, 800, 1100 and 900 kg ha^{-1}. To bridge the yield gap, attempts were taken giving emphasis on liming of acid soil, seed coating with lime, supplementation of deficient nutrient (Mo) very much essential for biological N_2 fixation, other essential soil nutrients and *Rhizobium* seed inoculation (Pattanayak, 2016, Pattanayak and Rao, 2014, Pattanayak and Sarkar, 2016) [16, 14, 16, 18, 15].

Green gram equivalent yield of pulse crops: The green gram equivalent yield of pulse crops varied between 240 and 763.6 kg ha^{-1}, lowest with horse gram and highest with cowpea. Based on productivity different pulse crops can be arranged in the order: cowpea > black gram > green gram > horse gram (Table 1). With the application of soil test based fertilizers, the mean productivity of four pulse crops was 336 kg ha^{-1} (green gram equivalent yield) without any amelioration measure. On an average 16 percent yield could be increased with adoption of seed inoculation with suitable *Rhizobium*. Asokan *et al.* (2000) [2] found that seed inoculation with bio fertilizers supplied the bioactive compounds such as vitamins, hormones, enzymes and essential nutrients such as nitrogen, phosphorus and molybdenum favorably influenced the plant vigor, morphology and metabolic processes, which ultimately enhanced the pods per plant and total yield. Combining acid soil ameliorative measure by seed coating with lime could increase the yield by 14 percent. In an experiment done by Hartley *et al.* (2004) [8], lime supply increased nodulation and yield of Serra Della. The beneficial effects of liming on nodulation and plant growth most likely resulted from the enhanced conditions for seedling growth and nodulation. Likewise combining Mo seed treatment with *Rhizobium* inoculation was very much effective in increasing crop productivity (45 percent higher yield). Various studies have reported that application of Mo enhances the yield in crops that grow in deficient soil (Liu, 2001; Min *et al.*, 2005; Xue-Cheng *et al.*, 2006) [10, 13, 26]. Sable *et al.* (2000) [21] reported significant influence of seed inoculation with *Rhizobium* and molybdenum on soybean roots growth and yield. Bambara & Ndakidemi (2010) [3] demonstrated that the Mo is less available in acidic soil and foliar application can overcome this problem. Although foliar application of Mo is beneficial, but the seed and soil applications remain effective for longer period under normal conditions. As the soil was deficient in Mo, its supplementation encouraged N_2 fixation and imparted other beneficial effects on crop growth. Combination of all the three POPs, seed coating with lime, *Rhizobium* seed inoculation and Mo seed treatment helped doubling the productivity from 336 kg ha^{-1} to 630 kg ha^{-1} even if in the problematic soil.

Total nutrient uptake: The total N uptake by the pulse crops varied between 26.1 and 97.3 kg ha^{-1}. Based on N uptake different pulse crops can be arranged in the order: black gram> cowpea > green gram > horse gram (Table 2). Seed treatment with Mo had greater influence on N uptake than other POPs. The total uptake of P by four pulse crops varied widely between 1.6 and 6.1 kg ha^{-1}. Based on P uptake different pulse crops can be arranged in the order: cowpea > black gram > green gram > horse gram (Table 2). The different POPs have significant influence on K uptake. Uptake of K was significantly different (higher) for cowpea than other three crops. Four different pulse crops differed significantly for their uptake of Ca and Mg (Table 2). Even though the uptake of Ca by horse gram and green gram crops were at par, but uptake by black gram crop was significantly higher compared to earlier pulse crops. Cowpea crop removed maximum Ca amongst the pulse crop (21.0 kg ha^{-1}). The total Mg uptake by pulse crops varied between 2.1 and 14.5 kg ha^{-1}, lowest through black gram and highest through cowpea. Similarly, combining all the POPs the total Sulphur uptake increased by 66 percent over S uptake of 0.6 kg ha^{-1} with *Rhizobium* inoculation alone.

Post-harvest soil characteristics: Initially the soil was strongly acidic in reaction (pH_w 4.49). Irrespective of the crops and the POPs at 7 DAS the pH in soil increased, thereafter decreased till the harvest of the crop. However, the package of practice of lime coating of seeds maintained higher pH comparatively for longer period of time compared to no lime POPs under each of the pulse crops. The rise in soil pH under non-limed POPs during initial days was mostly due to the impact of organics addition in buffering the soil pH and through irrigation water. The POPs had significant influence on OC status of soil, with STD organic carbon status decreased to 3.8 g kg^{-1} soil from 4.6 g kg^{-1} soil in initial stage. The status improved considerably with POPs and attended a maximum of 7.1 g kg^{-1} soil with all packages adopted in single package (Table 3). Initial available N status was 201 kg ha^{-1}. In the post-harvest soil it varied between 168 and 326 kg ha^{-1}, lowest under black gram and highest in cowpea. Comparing the available P status under different crops, it was observed that there was depletion with green gram crop but build up with rest of the crops. The all the POPs had significant positive influence on buildup of the status irrespective of the uptake (Table 3). Initial soil K and S was low i.e.108 kg ha^{-1} and 14.4 kg ha^{-1}. Irrespective of the POPs and crops its status increased in post-harvest soil and ranged from 162 to 208 kg ha^{-1} for K and 12.3 to 28.3 kg ha^{-1} for S (Table 3). The extra N uptake due to POPs ranged from 8 to 43 kg ha^{-1}, for P from 0.7 to 3.6 kg ha^{-1}, for K from 3 to 13 kg ha^{-1}, Ca from 4.5 to 16 kg ha^{-1}, Mg from 1.1 to 7.5 kg ha^{-1} and for S from 0.3 to 1.0 kg ha^{-1}.

Table 1: Green gram equivalent yield (kg ha^{-1}) of pulse crops as influenced by liming, *Rhizobium* inoculation of seed and molybdenum seed treatment

POPs Crops	-R	+R	R+S_L	R+Mo	R+S_L+Mo	Mean
Green gram	337.3	388.7	465.3	606.6	683.6	496.3
Black gram	335.0	344.0	413.6	647.0	719.3	491.8
Cowpea	431.6	568.0	620.0	701.3	763.6	616.9
Horse gram	240.0	264.0	286.0	310.0	352.6	290.5
Mean	336.0	391.1(16)	446.2(14)	566.2(45)	629.8(61)	
	Crop	POPs	C x POPs			
SE (m) ±	12.3	13.7	27.5			
LSD(p=0.05)	35.2	39.4	78.8			
CV (%)			10.0			

Table 2: Total Nutrient uptake by crops under the influence of lime coating of seeds, inoculation with *Rhizobium* and treatment with molybdenum

POPs Crops	-R	+R	R+S_L	R+Mo	R+S_L+Mo	Mean	-R	+R	R+S_L	R+Mo	R+S_L+Mo	Mean
	Total nitrogen uptake (kg ha^{-1})						**Total phosphorus uptake (kg ha^{-1})**					
Green gram	25.3	30.2	38.8	58.4	68.2	44.2	1.8	2.5	3.0	4.5	6.1	3.6(33)
Black gram	41.1	55.3	65.0	95.0	97.3	70.7	2.3	2.9	3.8	5.1	5.9	4.0(48)
Cowpea	37.8	47.6	56.7	73.4	80.2	59.1	2.3	3.1	3.7	5.4	6.0	4.1(56)
Horse gram	26.0	29.5	40.8	47.1	55.6	39.8	1.5	1.9	2.5	3.2	4.0	2.6
Mean	2.6	40.6(24)	50.3(54)	68.5(68)	75.3(85)		2.0	2.6(32)	3.2(22)	4.5(73)	5.5(111)	
	Crop	**POPs**	**C x POPs**				**Crop**	**POPs**	**C x POPs**			
SE (m) ±	0.6	0.7	1.4				0.07	0.07	0.15			
LSD(p=0.05)	1.9	2.1	4.2				0.2	0.2	0.4			
CV(%)			4.8						7.6			
	Total potassium uptake (kg ha^{-1})						**Total calcium uptake (kg ha^{-1})**					
Green gram	11.4	14.2	18.2	23.3	25.8	18.6	6.0	10.0	12.3	19.8	19.1	13.4
Black gram	12.2	15.4	17.6	22.2	24.7	18.4	5.5	12.8	15.8	19.5	23.2	15.3
Cowpea	14.8	19.8	22.9	28.1	27.9	22.7	10.8	14.9	20.8	27.4	30.70	20.9
Horse gram	12.7	15.1	18.6	21.3	25.6	18.6	6.1	8.1	13.4	15.5	19.4	12.5
Mean	12.8	16.1(25)	19.0(20)	23.8(47)	26.0(60)		7.1	11.4(62)	15.6(35)	20.5(79)	23.1(101)	
	Crop	**POPs**	**C x POPs**				**Crop**	**POPs**	**C x POPs**			
SE (m) ±	0.61	0.68	1.3				0.7	0.7	1.5			
LSD(p=0.05)	1.7	1.9	3.9				2.0	2.2	4.5			
CV(%)			12.1						17.4			
	Total magnesium uptake (kg ha^{-1})						**Total sulphur uptake (kg ha^{-1})**					
Green gram	2.6	4.1	5.5	7.9	9.1	5.8	0.5	0.7	0.9	1.4	1.5	1.03
Black gram	2.1	3.2	4.7	6.0	6.3	4.4	0.6	0.9	1.1	1.2	1.4	1.07
Cowpea	3.7	5.8	8.8	12.5	14.4	9.1	0.8	1.2	1.6	1.9	1.9	1.50
Horse gram	2.3	3.1	4.7	6.6	8.1	5.0	0.6	0.8	0.8	1.0	1.3	0.93
Mean	2.7	4.1(51)	5.9(44)	8.2(100)	9.5(130)		0.6	0.9(44)	1.1(23)	1.4(56)	1.5(66)	
	Crop	**POPs**	**C x POPs**				**Crop**	**POPs**	**C x POPs**			
SE (m) ±	0.2	0.2	0.5				0.02	0.02	0.04			
LSD(p=0.05)	0.7	0.8	1.6				0.05	0.06	0.1			
CV(%)			16.6						6.9			

Table 3: Post harvest soil nutrients status

POPs Crops	-R	+R	R+S_L	R+Mo	R+S_L+Mo	Mean	-R	+R	R+S_L	R+Mo	R+S_L+Mo	Mean
	Organic carbon (g/kg) status in post-harvest soil						**Available Nitrogen (kg ha^{-1}) in post-harvest soil**					
Green gram	4.0	5.1	6.1	6.7	8.0	6.0	177.6	195.0	210.3	220.3	235.3	208
Black gram	3.6	7.6	6.6	7.0	7.3	6.4	168.0	198.6	225.0	230.3	254.3	215
Cowpea	3.7	6.2	7.0	7.0	8.3	6.4	260.0	274.3	293.0	304.3	326.3	291
Horse gram	4.0	6.6	7.3	7.6	5.0	6.1	228.3	240.3	248.6	254.6	260.0	246
Mean	3.8	6.4	6.7	7.0	7.1		208.5	227.0	244.2	252.4	269.0	
	Crop	**POPs**	**C x POPs**				**Crop**	**POPs**	**C x POPs**			
SE (m) ±	0.43	0.4	0.9				4.9	5.4	10.9			
LSD(p=0.05)	1.2	1.3	2.7				14.0	15.6	31.3			
CV(%)			16.7						7.9			
	Available Phosphorus (kg ha^{-1}) in post-harvest soil						**Available Potassium (kg ha^{-1}) in post-harvest soil**					
Green gram	4.23	4.27	6.57	7.93	8.50	6.30	162.3	202.6	204.3	204.0	208.6	196.4
Black gram	22.11	28.23	29.10	30.33	34.00	28.76	165.0	171.3	176.2	179.0	190.3	176.3
Cowpea	20.63	24.83	27.27	31.93	32.80	27.49	172.3	176.0	181.0	194.3	200.0	184.7
Horse gram	21.27	25.20	26.90	31.63	32.43	27.49	165.7	171.0	178.6	181.0	199.3	179.1
Mean	17.06	20.63	22.46	25.46	26.93		166.3	180.2	185.0	189.5	199.5	
	Crop	**POPs**	**C x POPs**				**Crop**	**POPs**	**C x POPs**			
SE (m) ±	1.0	1.1	2.3				5.2	5.9	11.8			
LSD(p=0.05)	3.0	3.3	6.7				15.1	16.9	33.9			
CV(%)			18.2						11.1			
	Available Sulphur (kg ha^{-1}) in post-harvest soil											
Green gram	12.33	14.67	15.33	17.17	18.83	15.7						
Black gram	13.45	15.68	19.73	24.53	28.33	20.4						
Cowpea	13.80	16.47	18.83	20.30	24.43	18.8						
Horse gram	14.57	16.57	18.60	20.77	24.93	19.0						
Mean	13.5	15.9	18.1	20.7	24.1							
	Crop	**POPs**	**C x POPs**									
SE (m) ±	0.5	0.65	1.3									
LSD(p=0.05)	1.6	1.8	3.7									
CV(%)			12.3									

Conclusion

Lime coating of seed increased the soil pH from initial extremely acidic soil pH (4.49) to moderate range (pH 5.1 to 5.5), and thus indirectly favoured creation of more suitable medium for nutrient uptake by legumes. This condition creates a conducive soil environment for the crops that enables efficient use of both organic and inorganic nutrients which ultimately resulted in better performance of yield in legumes. Lime coating of pulse seeds was useful proposition for increasing the seed yield, when grown in acid soils by 14 percent compared over no lime coating practice. Molybdenum seed treatment @ 10 g sodium molybdate was capable of increasing the seed yield by 45 percent compared over no Mo treatment. Seed inoculation with efficient *Rhizobium* from external source bears the capacity to influence the pulse seed by at least 16 percent compared over no inoculation. Combination of all the three packages had the efficiency to double the productivity of pulse crops.

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