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Performance of *Lens culinaris* Medic. under integrated nutrient management practices and soil application of basic slagin eastern Indian old alluvial plains

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Abstract
An experiment was carried out during *rabi*2016-17 and 2017-18 at the farm of Regional Research Station (Old Alluvial Zone) under Uttar Banga Krishi Viswavidyalaya, Dakshin Dinajpur, West Bengal, India to study the effect of integrated nutrient management practice and soil application of basic slag on lentil (*Lens culinaris* Medic.). The experiment was laid out in factorial randomised block design with nine treatment combination and replicated thrice. The experimental soil was initially slightly acidic, medium in available nitrogen, low in available phosphorus and low in available potassium. Integrated nutrient management practice with 75% of recommended dose of fertilizer + 5 t ha^{-1} FYM + seed inoculation with *Rhizobium* performed as the best treatment amongst the treatment combinations in terms of higher number pod plant^{-1}(113.4), higher number of seed pod^{-1}(1.78), and higher seed yield (1293.7 kg ha^{-1})with better return rupee^{-1} of investment(1.79). This treatment fetched 21.28% yield increment of lentil with higher number of root nodule formation plant^{-1} at 45 DAS (13.61) and 60 DAS (16.78) over the sole use of chemical fertilizer. Soil application of basic slag@ 20% of the lime requirement also showed its potentiality in seed yield of lentil (1289.6 kg ha^{-1}), better return rupee^{-1} of investment of (1.89) with a higher number of root nodule formation plant^{-1}at 45 DAS (15.28) and 60 DAS (16.64) compared to the treatment with no use of soil ameliorative materials at old alluvial soil of the eastern India.

Keywords: basic slag, economics, INM, lentil, seed yield

Introduction
The cultivated species of grain legumes are found in the world is about 60 (Hedley, 2001) [5]. Amongst the cultivated species, the *Lens culinaris* Medic. is widely adopted annual legume pulse crop in cool climate conditions and is traditionally also grown as a rain fed crop during *rabi* season. Lentil seed is a rich source of protein (up to 28%) in human diets in arid and semiarid areas (Sarker *et al.*, 2003) [13]. The Food and Agriculture Organization and National Advisory Committee of India have recommended 104 g of pulses per capita per day under the minimum nutritional programmes in purely vegetarian diet (Gill, 2013) [3]. Lentil is a common pulse crop in the old alluvial plains of West Bengal under rice based cropping systems. Dakshin Dinajpur district covers a major area under old alluvial zone and characterised by clay-loam soil having pH between 4.5 and 5.5 with annual rainfall of 1500-1700mm. Though lentil is the common pulse crop in this district, the productivity is declining compared to the state average productivity. The poor productivity of lentil might be due to imbalance and non-judicial application of synthetic fertilizers in growing crops round the year in a same piece of land and non-availability of essential plant nutrients due to soil acidity. Imbalanced use of fertilizers may cause deterioration of soil health, soil acidifications and lower humic acid contents.

In West Bengal agriculture scenario is mostly of rice intensive in nature. In present day agriculture, there is increasing concern about the sustainability in productivity of soils as a resource base to meet the demand of the expanding human population. Inintensive cultivation practices and escalating contribution towards food production scenario cannot be attained without external supply of adequate amount of nutrients. In spite of the significant contribution of mineral fertilizers to the increased production system, a steady decline in fertilizer use efficiency for production of agricultural crops has now become a matter of serious concern. The need for continued increase in agricultural production to meet the ever expanding human and livestock population coupled with the inability of chemical fertilizers to maintain long-term soil health and crop productivity in intensive cropping system have underlined the need for integrated sources of nutrient such as the combination of chemical fertilizers, organic manures, bio-fertilizers *etc*. (Hegde *et al.*, 1999) [6].

Nitrogen fixation in legume crops like lentil is governed by *Rhizobium*s trains as well as nitrogen and phosphorus availability in the soil. Phosphorus and nitrogen play specific role in symbiotic nitrogen fixation through nodulation and fixation process (O'Hara *et al*., 2002) [11]. Symbiotic nitrogen fixation consumes large amounts of energy and has high demand of phosphorus (Schulze *et al.*, 2006) [14] and the metabolism process which generates energy is strongly dependent upon the availability of phosphorus (Israel, 1987; Plaxton, 2004) [7, 12]. Soil reaction has a significant influence on availability of plant nutrients and activities of beneficial soil microorganisms. Soil acidity results in the decline in Ca and Mg content leading to their deficiency for plants growth. Both soluble and exchangeable Ca decreases with decreasing pH (Haynes and Ludecke, 1981) [4].

Phosphorus is particularly sensitive to pH and can become a limiting nutrient in acidic soils. As the old alluvial soil is acidic in nature, there might be some limitations in availability of essential nutrients leading a low productivity of lentil. Basic slag is a potential liming agent to increase the precipitation and sorption of metals in soil and improves physico-chemical properties of the soil. Basic slag is a good, alternative soil liming material for the acidic soil. The real value of basic slag is not lying upon the nutrient content in it but in its basic soil liming properties. Basic slag is a by-product obtained from steel industry contains CaO, MgO, $SiO_2$and micronutrients, such as copper, zinc, manganese and iron. Calcium and magnesium compounds, because of their basicity, improve soil pH and also serve as plant nutrients.

Keeping this in view an experiment was undertaken to assess the effect of integrated nutrient management practice and application of basic slug in soil as a liming material on lentil at the old alluvial zone of West Bengal, India.

Materials and Methods

The field experiment was conducted at the farm of Regional Research Station (Old Alluvial Zone), Uttar Banga Krishi Viswavidyalaya, Majhian, Dakshin Dinajpur, West Bengal, India in 2016-17 and 2017-18 during *Rabi*. The farm is situated at $26^0$19'86" N latitude and $89^0$23'53" E longitude and at an altitude of 43 meter above mean sea level. This zone is characterised by annual rainfall of 1500-1700 mm and pre-humid condition. The experimental soil was slightly acidic in reaction (pH 5.2) and texturally clay-loam in nature. The status of the mineralizable nitrogen, available phosphorus and available potash in the experimental soil were medium (N - 310 Kg ha^{-1}). Low (P_2O_5 -42 kg ha^{-1}) and High (K_2O 360kg ha^{-1}) respectively. The experiment was laid out in factorial randomized block design with nine treatment combinations in experimental plot sized 3 m x 4m and replicated thrice. The treatment comprised of the different integrated nutrient management practices *viz.* 30:60:30 kg N- P_2O_5- K_2O ha^{-1} as recommended dose of fertilizer(RDF) ; 75% of recommended dose of fertilizer + 5 t ha^{-1} FYM + seed inoculation with *Rhizobium*; 75% of recommended dose of fertilizer + 2.5 t ha^{-1}Vermicompost+ seed inoculation with *Rhizobium.* Soil application of basic slag as liming material @ 10% of lime requirement and @ 20% of lime requirement had also been used as treatments along with no application of liming material. In the treatment combination under nutrient management practice, the organic manures were applied along with chemical fertilizers, based on the blanket application *in lieu* of the nutrient content basis as the nutrient content in the organic manure varies widely with the procedure of preparation, site and raw material used. The basic slag had been applied in the soil as a liming material after calculating the lime requirement of the experimental soil using the following formula.

LR (mg $CaCO_3$ kg^{-1}) = LBC x (target pH- [initial pH-0.6]).

The variety chosen for the experiment was WBL-77, popularly known as Moitree. It takes 115-120 days to mature. This variety is characterised by erect plant, bluish purple flowers, and small oval seed with dark mottled seed coat with red cotyledons. The fertilizers were applied in full dose as per the treatment schedule just after laying out of the experiment. No topdressing of fertilizer was done. Well decomposed farm yard manure (FYM), vermicompost, basic slag were applied as per the treatment schedule on the fifth day of application of chemical fertilizers during both the years of experimentation. Keeping the seed rate of lentil as 30 kg ha^{-1}, the seed rate for each plot sized 12 sq. m was calculated. The seeds of lentil was inoculated with the *Rhizobium leguminosarum* before sowing as per the treatment schedule. All other agronomic operations were performed as per recommendations of the crops. Economic analysis was carried out using the prevailing market price. The numbers of root nodules were counted at 45 and 60 days after sowing from five randomly selected plants in each plot after uprooting the plants with the help of *Khurpi*. The roots were then carefully washed with water and the root nodules were kept in thermostatically controlled oven at 80°C for 20 hours to obtain constant dry weight and finally weights of nodules from each plot were recorded in mg. The soil and plant samples were analysed at the laboratory following the standard methods.

Data were collected on yield attributing character of lentil. The statistical analysis of data was done following the procedure for analyzing factorial RBD (Cochran and Cox, 1977) and by using statistical software MSTAT-C version 2.1(Michigan State University, USA). Significant differences between the treatments were compared with the critical difference at ± 5% probability by LSD.

Results and Discussion

The plant population per meter and row length recorded in each treatment at 30 days after sowing and at harvest and found non-significant in all the treatments. However, significant highest number of pod $plant^{-1}$(113.4), number of seeds $plant^{-1}$(1.78)of lentil was observed in the plot where crops received the nutrients in combination with inorganic and organic along with seed inoculation with *Rhizobium**i.e*75% of the recommended dose of fertilizer along with FYM (5 t ha^{-1}) and *Rhizobium* seed inoculation(Table 1). But these values were statistically at par with the plots where the crops received 75% of the recommended dose of fertilizer along with Vermicompost (2.5t ha^{-1}) and seed inoculation with *Rhizobium*. Nutrient management practice devoid of any organics and seed inoculation with bio-fertilizer showed poor result. Though the 1000-seed weight in the treatment schedule was statistically non-significant but the highest number of pod $plant^{-1}$and number of seeds $plant^{-1}$ in the integrated nutrient management practice with 75% of the recommended dose of fertilizer along with FYM @5 t ha^{-1} and *Rhizobium* seed inoculation reflected in the highest seed yield of lentil (1293.7 kg ha^{-1}). 21.28% yield increment of lentil has been observed with this treatment over the recommended dose of chemical fertilizer. The organic sources of nutrients like FYM are not only the store house of the plant nutrients but also improves the physico-chemical as well as biological properties of the soil. Side by side FYM is a good substrate for the bio-fertilizers with a buffering tendency. FYM also increases fertilizer use efficiency applied in inorganic form to the crop, it also supplies micronutrients and helps in making available of the soil phosphorus even in the slightly acidic soil. Inorganic fertilizers in combination of organics might have played a key role in enhanced productivity of the lentil. Increased yield components of lentil were also recorded in the plots where the soil was ameliorated with the basic slag @ 20% of Lime Requirement in comparison with basic slag @10% of the Lime Requirement and no use of basic slag. Highest number of pod plant^{-1}(110.6), number of seeds plant^{-1}(1.82) were observed in the treatment where soil was ameliorated with basic slag @ 20% of Lime Requirement and recorded significantly highest yield (1289.6 kg ha^{-1}) with the same treatment. An yield increment of 28.42% in lentil has been observed with the application of basic slag @20% of the lime requirement over the no use of any liming material. Ali and Shahram (2007) [1] also reported that slag proportionately enhances the Phosphorus availability in acid soil. The basic slag upon dissolution releases Ca and Mg which neutralizes soil acidity thus increases soil pH and consequent increase the availability in P, Ca and Mg in soil. Basic slag contains an appreciable amount of Phosphorus which may also contribute in the increasing trend of available Phosphorusin soil and in increasing plant growth as well as the productivity of the lentil.

Table 1: Effect of integrated nutrient management practice and basic slag on yield and yield attributes of lentil (Pooled data of two years)

INM Practices	Pods plant^{-1}	Seeds pod^{-1}	1000-seed weight (g)	Seed yield kg ha^{-1}	Return rupee $^{-1}$ invested
RD 30:60:30 ($N:P_2O_5:K_2O$ kg ha^{-1})	85.6	1.12	20.2	996.8	1.18
75% RD+ FYM 5t ha^{-1}+ *Rhizobium*	113.4	1.78	20.6	1293.7	1.79
75% RD+ Vermicompost 2.5t ha^{-1}+ *Rhizobium*	112.1	1.65	20.4	1208.9	1.48
S.Em (+)	1.60	0.05	0.69	32.93	0.053
C.D (P=0.05)	4.8	0.15	NS	98.7	0.16
Application of Basic slag					
No Basic slag	95.4	1.22	20.2	1004.2	1.10
10% of LR by Basic Slag	105.1	1.51	20.5	1185.6	1.46
20% of LR by Basic Slag	110.6	1.82	20.5	1289.6	1.89
S.Em (+)	1.60	0.05	0.69	32.93	0.053
C.D (P=0.05)	4.8	0.15	NS	98.7	0.16

Integrated application of chemical fertilizer, organic material along with seed inoculation with bio-fertilizers can successfully be recommended for lentil crop as the highest return rupee^{-1} of investment (1.79) was observed where the crop received a combination 75% of the recommended dose of chemical fertilizer and FYM (5 t ha^{-1}) along with seed inoculation with *Rhizobium* (Table 1). It was followed by the treatment combination of 75% of the recommended dose of fertilizer + Vermicompost@ 2.5 t/ha + seed inoculation with *Rhizobium* (1.48). Despite higher production cost in these treatments there was a noticeable return rupee^{-1}of investment due to the higher magnitude of seed yield. Lowest return per rupee of investment (1.18) was observed where the crop received only chemical fertilizer as a source of plant nutrient due to the lower seed yield. Soil application of basic slag showed higher return rupee^{-1} of investment in lentil cultivation. The highest return rupee^{-1} of investment (1.89) was obtained with soil application of basic slag @20% of the Lime Requirement followed by soil application of basic slag @10% of the Lime Requirement (1.46). Availability of the plant nutrients for its better uptake and higher seed yield applying those soil ameliorative measure in lentil cultivation might be the reason behind the higher return rupee^{-1}of investment in these treatments.

The integrated nutrient management practices exerted significantinfluence upon number of root nodule plant^{-1}and dry weight of root nodule plant^{-1} of lentil at 45 and 60 days after sowing (Table 2). The number of root nodules per plant increased significantly in all the nutrient management practices over sole application of recommended dose of inorganic fertilizer in both the observation recorded at 45 and 60 days after sowing. The maximum root nodules plant^{-1}13.61 and 16.78were recorded with the application of 75% of the recommended dose of fertilizer + FYM @ 5 t/ha + seed inoculation with *Rhizobium* at both the stages of crop growth. However, this treatment was found statistically at par upon the formation of root nodules with other option of the integrated nutrient management practice *i.e* 75% of the recommended dose of fertilizer + Vermicompost@ 2.5 t/ha + seed inoculation with *Rhizobium*. The significantly lowest number of root nodules plant^{-1}, 9.13 and 10.02were recorded where crops received recommended dose of fertilizer devoid of any organics at 45 and 60 days after sowing respectively. All the integrated nutrient management practiced over here recorded significantly higher dry weight of root nodules plant^{-1} as compared to sole application of inorganic fertilizer. The application of 75% of the recommended dose of fertilizer + FYM @ 5 t/ha + seed inoculation with *Rhizobium* resulted maximum dry weight of root nodules 9.23 mg plant^{-1} and 12.96 mg plant^{-1}at 45 and 60 days of crop growth. It was found statistically at par with 75% of the recommended dose of fertilizer + Vermicompost@ 2.5 t/ha + seed inoculation with *Rhizobium*. Being a legume, lentil fixes atmospheric nitrogen and improves the soil fertility. Integrated nutrient management in lentil has a great importance as it encourages the root nodulation, growth and productivity in addition to keeping soil health sustained. Biological nitrogen fixation by the *Rhizobium* sp. in root-nodules of lentil is one of the most important ways in which atmospheric nitrogen enters in to the biosphere where living organisms exist in natural state. The combination of organic and inorganic sources of nutrients in treatments along with *Rhizobium* was supposed to increase the population and activity of the nitrogen fixing bacteria in the rhizosphere of the lentil crop which encouraged the availability and sufficient supply of plant nutrients for better nodule formation.

Table 2: Effect of integrated nutrient management practice and basic slag on nodulation and nutrient uptake of lentil (Pooled data of two years)

INM Practices	No. of root nodule plant^{-1}		Dry weight of root nodule (in mg) plant^{-1}		Nitrogen kg ha^{-1}	Phosphorus kg ha^{-1}	Potassium kg ha^{-1}
	At 45 DAS	At 60DAS	At 45DAS	At 60 DAS			
RDF 30:60:30 ($N:P_2O_5:K_2O$ kg ha^{-1})	9.13	10.02	5.81	7.21	20.25	9.16	18.15
75% RDF+ FYM 5t ha^{-1}+ *Rhizobium*	13.61	16.78	9.23	12.96	27.62	17.35	30.16
75% RDF+ Vermicompost 2.5t ha^{-1}+ *Rhizobium*	12.89	15.12	8.85	11.89	26.85	16.52	28.29
S. Em (+)	0.50	0.60	0.36	0.40	0.66	0.63	0.78
C.D (P=0.05)	1.50	1.80	1.10	1.20	1.97	1.88	2.35
Application of Basic slag							
No Basic slag	7.32	9.61	5.26	6.98	18.28	7.32	15.68
10% of LR by Basic Slag	13.03	15.67	8.95	11.96	25.74	16.86	28.77
20% of LR by Basic Slag	15.28	16.64	9.68	13.12	30.70	18.85	32.15
S. Em (+)	0.50	0.60	0.36	0.40	0.66	0.63	0.78
C.D (P=0.05)	1.50	1.80	1.10	1.20	1.97	1.88	2.35

Perusal of the data, it is revealed that the application of basic slag @ 20% of the Lime Requirement played a significant role to increase the number of root nodule plant^{-1}and dry weight of root nodule plant^{-1} of lentil crop at 45 and 60 days after sowing in comparison to the other soil ameliorative measure and no measure (Table 2). The highest values of number of root nodule plant^{-1} at 45 and 60 DAS have been observed as 15.28and 16.64 respectively where experimental soil received basic slag @ 20% of the Lime Requirement. Significantly highest dry weight of root nodule plant^{-1} also observed using the same treatment compared to the no use of basic slag in the treatment schedule. Nitrogen fixation in legumes is strongly affected by soil pH. Nitrogen fixation is reduced sharply under pH less than 6.0 and results reduced relative yields due to inhibition of nodule initiation in low pH. Low in *Rhizobium* population and inhibition in nodule initiation, probably responsible for the poor nodulation in acidic soil (Munns1968, 1970). Application of basic slag was supposed to increase pH in the old alluvial soil effectively and thus it enhanced nodule formation as well as the ambient nitrogen fixation process towards better seed yield.

After whole plant analysis in the laboratory, the results clearly indicated a significant effect of integrated nutrient management practices and application of basic slag in the uptake of the plant nutrients of lentil crop over the sole application of inorganic fertilizers and no use of basic slag (Table 2).It was noticed that the uptake of nitrogen, phosphorus and potassium varied greatly due to variation in the nutrient management practices. The uptake of the plant nutrients by lentil crop increased steadily and significantly with the use of organic materials in combination with inorganic fertilizers. The highest uptake of Nitrogen, phosphorus and potassium recorded as 27.62 kg ha^{-1}, 17.35kg ha^{-1} and 30.16 Kg ha^{-1} respectively in the plot where crops received the integrated nutrient management practice comprising 75% of the recommended dose of fertilizer + FYM @ 5 t/ha + seed inoculation with *Rhizobium* followed by 75% of the recommended dose of fertilizer + vermicompost @ 2.5 t/ha + seed inoculation with *Rhizobium.* Lowest plant nutrient uptake was recorded where the crop received only chemical source of nutrient. Higher plant nutrient uptake by lentil in integrated nutrient management practice was mainly due to better crop growth, higher crop productivity apart from some contribution by increased nutrient content in the plant parts. Poor growth and poor crop productivity was primarily responsible for lowest plant nutrient uptake by the crop received only chemical source of plant nutrients. Application of basic slag @20% of the Lime Requirement also showed significantly higher value of the uptake of the nitrogen (30.70 kg ha^{-1}), Phosphorus (18.85 kg ha^{-1}) and Potassium (32.15 kg ha^{-1}) followed by application of basic slag @10% of the Lime Requirement. Lowest value of the uptake of the plant nutrient has been observed where no soil ameliorative measure was taken. The absorption of plant nutrients by the crops depends on their ionic forms in the rhizosphere, which is greatly influenced by soil acidity and the concentrations of nutrients in the soil (Masud *et al.*, 2014). The reduction in soil acidity by applying basic slag might have increased the pH and availability of the plant nutrients in the root zone and ultimately its uptake by the crop. Neural pH also increases root proliferation by reducing toxic effects of Aluminium (Tang *et al*., 2003) [15] and thus application of basic slag might have enhanced the uptake of plant nutrients by the lentil crop and attributed increased yield of lentil. No interaction effect between integrated nutrient management practice and soil application of basic slag has been observed in this experimentation.

Conclusion

Results of the study showed that the combined application of 75% of the recommended dose of fertilizer and farm yard manure FYM @ 5 t ha^{-1} along with seed inoculation with *Rhizobium* was more beneficial in improving yield components, plant nutrient uptake and seed yield of lentil. Results also indicated a promising potential for basic slag as an alternative material for liming of acid soil in terms of better plant nutrient uptake as well as yield of lentil at the old alluvial zone of eastern India.

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