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Comparative Effectiveness of Bio-inoculant and Enriched Compost on Lentil (*Lens culnaris* Medik.) Yield under Acid Soil

Christy B.K. Sangma[1], Dwipendra Thakuria[2]

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ABSTRACT

Background: The advancement of pulse crops, especially lentil (*Lens culinaris* Medik.) in acid soils is very challenging due to poor nodulation efficiency and nitrogen fixation. The build-up of *Rhizobium* population near the germinating seeds (spermosphere) in acid soils with seed inoculation alone is not sufficient, thus limiting its survivability, multiplication and poor *Rhizobium*-legume interactions. The present investigation aimed at effectiveness of native *Rhizobium* strain tolerant to acid soil through seed inoculation and through enriched compost fortified with *Rhizobium.*

Methods: For this a field experiment on lentil crop (variety PL-8) was conducted in acid soil with 9 treatments combination: T1: 100% RDF (@20:60:20 kg N-P-K ha^{-1}), T2: 50% RDF, T3: seed inoculation (SI) with NR2+EC 1+50% RDF, T4: SI with ER (CK1)+EC 1+50% RDF, T5: SI with NR2+EC 2+50% RDF, T6: SI with ER (CK1)+EC 2+50% RDF, T7: SI with NR2+EC 4+ 50% RDF, T8: SI with ER (CK1)+EC 5+50% RDF, T9: SI with NR2+ EC 3+50% RDF.

Result: The nodulation efficiency, pod and seed yield and the soil parameters after the harvest of crop were significantly higher in treatments receiving enriched compost amended with *Rhizobium*, PSB and RP. Thus, seed inoculation along with enriched compost amended with native *Rhizobium*, PSB and RP had showed great potential in supporting higher nodulation efficiency and yield of lentil crop grown under acid soil.

Key words: Acid soil, Lentil, Native *rhizobium*, Niche specific, Symbiosis.

INTRODUCTION

Lentil (*Lens culnaris* Medik.) yield and productivity are highly impacted (dipping by 71%) in acid soils by the reduced ability of symbiotic rhizobia (*Rhizobium leguminosarum* bv. viceae -pea cross inoculation group) to perform in low-pH conditions and its population (rhizobia) in the rhizosphere soil drop markedly when the soil pH goes below 6.0 (Jida and Assefa, 2014). The critical soil pH level for lentil growth is reported to be 5.7 and growth is severely reduced, stunted and necrotic leaves are formed at pH values below 3.7, 3.7 and 4.5, respectively; the highest numbers of nodules in lentil are formed above pH 5.5 and no nodulation occurs below pH values of 4 (Burns *et al.,* 2017). So, despite being the nutritious food, the lentil crop is not popular among the growers in acidic soils and the reason is its difficulty in establishing under stress conditions and poor performance in terms of yield.

The cross inoculant group-specific *Rhizobium* biofertilizer is crucial for effective legume-*Rhizobium* interactions in acidic soils. This *Rhizobium* inoculant survivability in acidic soil conditions is the major drawback upon seed treatment alone, without providing a favourable environment for the growth and multiplication of *Rhizobium* in the rhizosphere region (Hartley *et al.,* 2012). So, a strategy is framed to tackle these constraints of lentil production in the present research, which is by formulating the *Rhizobium* compatible enriched compost supplemented with cellulose degrading bacteria (CDB), phosphorus solubilizing bacteria (PSB) and fortified with rock phosphate (RP) to use along with the seed inoculation solely in the lentil crop and its cross inoculation group to increase the nodulation and nitrogen (N_2) fixation and increase crop production as a whole keeping in mind the health of the soil too. The philosophy behind the addition of RP+PSB in the *Rhizobium* fortified compost is to support better phosphorus (P) nutrition in the crop rhizosphere for higher N_2-fixation under phosphorus (P) deficient acid soil.

[1]ICAR Research Complex for NEH Region, Umiam-793 103, Meghalaya, India.
[2]College of Post Graduate Studies in Agricultural Sciences, Central Agricultural University, Imphal, Umiam-793 103, Meghalaya, India.

Corresponding Author: Christy B.K. Sangma, ICAR Research Complex for NEH Region, Umiam-793 103, Meghalaya, India.
Email: christysangma@gmail.com
ORCID: 10000.0003-2486-9520

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MATERIALS AND METHODS

Enriched compost types

Five (5) types of enriched composts were prepared with the use of crop residues *viz*. rice straw, maize stalk and banana leaves mixed with the weed biomass *viz*. *Eupatorium* spp., *Ambrosia* spp. and broom grass following

Berkley rapid composting method (Raabe, 2001) with slight modification according to the suitability for the region and availability of substrates. The efficient cellulose decomposer (CDB) was inoculated in all the compost pits. Phosphorus solubilizing bacteria (PSB) and *R. leguminosarum* (NR and ER) are inoculated in specific compost types. The compost types prepared were: (i) Enriched Compost 1 (EC1): Normal compost, (ii) Enriched Compost 2 (EC2): Rock phosphate (RP)+Phosphorus solubilizing bacteria (PSB) compost, (iii) Enriched Compost 3 (EC3): native *Rhizobium* (NR) compost, (iv) Enriched Compost 4 (EC4): RP+PSB+NR and (v) Enriched Compost 5 (EC5): RP+PSB+exotic *Rhizobium* (ER).

***Rhizobium leguminosarum* bv. viceae strains**

Rhizobium leguminosarum bv. viceae CK1 strain, is the exotic strain (ER) used as reference was obtained from All India Network Project on Biofertilizers and Soil Biodiversity (AINP), Solan Centre, Dr. YSPUH&F, Solan, HP, India and it is suitable for acidic soil conditions. *Rhizobium leguminosarum* bv. viceae NR2 strain is the native strain isolated from acidic soils of North Eastern Hill region, India.

Preparation of liquid formulation for seed treatment

For preparation of liquid formulation for both native and exotic *Rhizobium* isolates (2 strains) YEMA (Yeast Extract Mannitol Agar) media (with composition of K_2HPO_4 0.5 g, $MgSO_4$ 0.2 g, NaCl 0.1 g, Mannitol 10 g, Yeast extract 0.5 g and Agar agar 15 g and adjusted to pH 7.0, Vincent, 1970) was prepared where chemical amendments *viz.* polyninyl pyrollidone (PVP) as additives, carboxymethyl cellulose sodium salt as adjuvants, tween 20 as surfactants and ascorbic acid as an antioxidant were added. The liquid formulations were autoclaved and the *Rhizobium* strains were inoculated separately and incubated at 28±1°C and from the 4th day viable population count by serial dilution technique was carried out until the required population was achieved (10^8 cfu/ml). When the formulation was ready the required amount of seeds were washed with the tap water thoroughly and then 100 ml of liquid formulations were mixed with the 200 g of sterile compost and the seeds were mixed with the paste. Thereafter it was shade dried for 2 h and sowing was done.

Field experiment

The field experiment was conducted in acidic soils of ICAR-RC-NEHR farm, Umiam, Meghalaya located in 250 41′ 18.36″ latitude and 910 55′04.38″ longitude and at the elevation of 1010m above mean sea level during *rabi* season of 2020-21. Nine (9) treatments in 3 blocks (replications) were laid out in RBD in the field experiment and lentil crop (variety-PL 8-140 days duration) was grown. Treatment combinations were: T1: 100% Recommended dose of fertilizer (RDF) @ 20:60:20 kg ha^{-1} NPK, T2: 50% RDF @ 10:30:10 kg ha^{-1} NPK, T3: Seed inoculation (SI) with native *Rhizobium* (NR2)+Enriched compost 1 (EC1)+50% RDF, T4: SI with exotic *Rhizobium* (ER)+ Enriched compost 1 (EC1)+50% RDF, T5: SI with NR2+Enriched compost 2 (EC2)+50% RDF, T6: SI with ER+Enriched compost 2 (EC2)+50% RDF, T7: SI with NR2+Enriched compost 4 (EC4)+50% RDF, T8: SI with ER+Enriched compost 5 (EC5)+50% RDF and T9: SI with NR2+Enriched compost 3 (EC3)+50% RDF. The layout of the field experiment is in RBD with 9 treatments and 3 replications. Enriched compost of 5 types was applied @ 2 t ha^{-1}.

Plant growth and yield parameters

Plant growth parameters *viz.* plant height, leaf area, leaf area index, nodule number and weight were recorded following the standard procedure. The leaf area (LA) and leaf area index (LAI) in the lentil was determined by following the destructive gravimetric method (Gratani and Bombelli, 2000). Yield attributes *viz.* number of branches, number of pods, biomass yield and total yield were recorded.

Soil analysis

Soil samples were analyzed for pH (1:2.5 soil/water suspension) using a standard pH meter. Soil organic carbon (SOC) in air-dry soil sample was determined by following wet oxidation method described by Walkley and Black (1947). The alkaline permanganate oxidation method described by Subbiah and Asija (1956) was followed for the estimation of available nitrogen in soil (Avail. N). Available phosphorus (Avail. P) in soil was determined by method described by Bray and Kurtz, (1945). Available potassium (Avail. K) was determined in neutral 1N ammonium acetate by Hanway and Heidel (1952) method in flame photometer. DTPA extractable Zinc (Zn) was determined in an atomic absorption spectrophotometer (AAS) after shaking a soil in 0.005M DTPA (diethylene triamine penta acetic acid)+0.01M $CaCl_2$+0.1M Triethanolamine (TEA) adjusted to pH 7.3 (Lindsay and Norvell, 1978).

Soil biochemical properties {dehydrogenase (DHA), acid-phosphomonoestrases (PHA) and urease activities} were determined at 60 days of plant growth. DHA {µg (TPF) g^{-1} (dw) soil h^{-1}} in air dried soil samples was determined as per the method described by Casida *et al.* (1964). PHA {µg p-nitrophenol g^{-1} (dw) soil h^{-1}} in fresh soil samples was determined as per the procedure described by Tabatabai and Bremner (1969). Urease activity {µg NH_4 released g^{-1}soil h^{-1}} was determined by following the method described by Tabatabai and Bremner (1972).

Statistical analysis

All univariate analyses were performed using SPSS v21.0 (SPSS Inc., Chicago, IL, USA). Data generated from the field experiments were subjected to the statistical analyses of variance appropriate to the experimental design. Data were assessed by Duncan's multiple range tests (Duncan, 1955) with a probability P≤0.05. Least significant difference (LSD) between means was calculated using the SPSS program.

RESULTS AND DISCUSSION

Plant growth and yield parameters of lentils under field experiment

The addition of *Rhizobium* compatible enriched compost on lentil crops had a various positive effect in the present experiment under field conditions. Even though the experiment was conducted in the strong acidic soils with pH 4.11 at the initial crop growth the lentil plant performed well by attaining the medium height, good nodulations and yield as well as maintaining the soil fertility. The lentil crop attained a maximum height (Fig 1) of 9 cm (T6) tall in 30 days and a minimum of 4.47 cm height which was observed under the treatment T2 {50% RDF @ 10:30:10 kg ha^{-1} NPK}. At 90 days the plant height of lentils was in the range of 20-27 cm and grows up to 30-33 cm height till 120 days, although a significant difference (P≤0.05) was not observed between the treatments in 90 and 120 days. Under field condition, the height of the lentil plants was taller compared to the pot experiment with seed inoculation alone (Sangma and Thakuria, 2020) but shorter than the average height attained in other parts of India (approximately 60 cm height, Kundu *et al.,* 2017). A significantly higher number of branches (P≤0.05) was observed under the treatment T6 (3.7 no.) followed by T8 treatment in 30 days (Table 1) of plant growth. At 90 and 120 days significantly higher branches were observed in the treatments T5, T6 and T7. The height of the lentil plant and the number of branches formed was reported to be affected by number of factors *viz.* the type of soil in the experiment, nutrient management system, *Rhizobium* inoculation and P nutrition to a greater extent as it is required for the cell division in the plants (Virk *et al.,* 2024).

The effect of different treatments was visible on the number of nodules formed in the lentil crop (Table 2). The number of nodules form was found significantly higher in the treatment T5 {SI with NR2+Enriched compost 2 (EC2)+50% RDF} followed by the T7 {SI with NR2+ Enriched compost 4 (EC4)+50% RDF} at 120 days of lentil crop growth. The fresh weight of the lentil was found maximum in the treatment T7 consecutively from 30 days to up to 120 days. The significantly higher nodulation in lentil, with the seed inoculation in combination with enriched compost and 50% of RDF, suggested that the adequate population of rhizobia was supplied to the crop through dual inoculation, which ultimately enhances the nodule formation. Similar results were obtained Singh *et al.* (2016). In the present experiment, the nodule formation was very low up to 60 days of crop growth and this delay in the nodule formation and the onset of N2 fixation even in the presence of adequate populations of rhizobia was many times due to the low temperature.

The leaf area (Table 3) of the lentil plant measured after every 30-day interval showed that after 30 days of plant growth, the significantly higher (P≤0.05) leaf area of 63.91 cm^2 was observed in the T5 treatment followed by treatment T7. The leaf area in all the treatments was found to increase from 30 days to 90 days. The highest leaf area attained in the present experiment was 264.36 cm^2 in T7 treatment and a similar leaf area in lentil was observed by Veeresh (2003) with increased P nutrition in the soil. The leaf area index (LAI) also followed the same pattern as that of the leaf area. It was recorded highest in the treatment T5 in 30 days and in 90 days T7 showed the highest with 3.37. The leaf area (LA) and leaf area index (LAI) is affected by the nutrient management system and at optimum nutrient content, both LA and LAI attain the maximum value (Turuko and Mohammed, 2014). The inoculation of *Rhizobium* spp. specific to the crop was also reported to increase the photosynthetic rate of the plant by increasing the leaf area as well as the dry matter production in the crop (Thakur and Panwar, 1995).

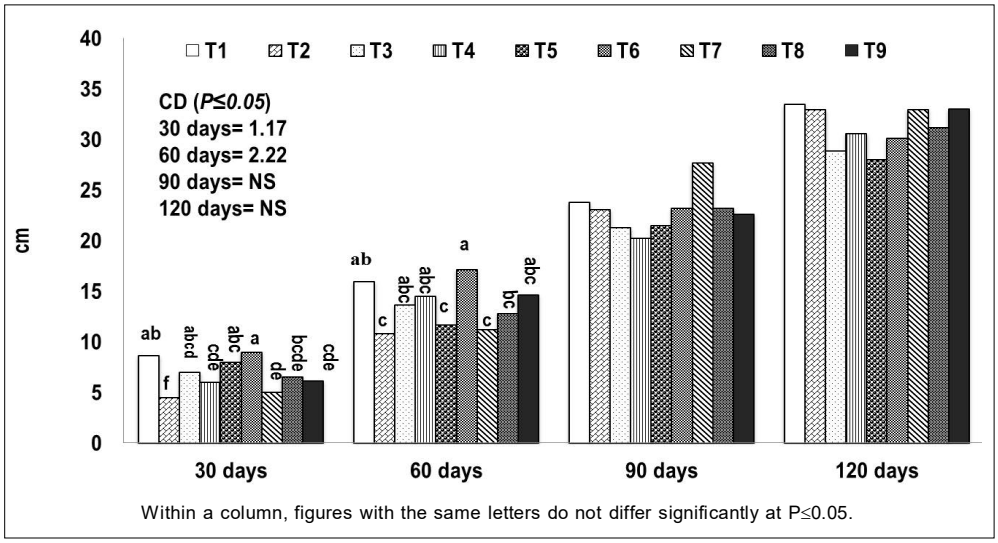


Fig 1: Lentil plant height at 30 days intervals up to 120 days under field experiment.

Table 1: Number of branches observed in lentil crop at 30 days interval up to 120 days and soil parameters at the initial and after the harvest of lentil crop.

Treatment	Number of branches				Treatment	pH	SOC (%)	Avail. N	Avail. P	Avail. K	Zn (ppm)
	30 days	60 days	90 days	120 days							
Initial	4.11^{d}	0.87^{ab}	203^{e}	9.68^{g}	183^{a}	1.59^{f}					
T1	2.7^{abc}	3.7^{cd}	7.0^{ab}	10.0^{abcd}	T1	4.31^{a}	0.89^{ab}	285^{c}	14.10^{f}	170^{b}	2.29^{ab}
T2	1.3^{de}	3.0^{cd}	5.0^{b}	7.0^{d}	T2	4.19^{c}	0.83^{b}	174^{f}	9.06^{h}	119^{g}	1.71^{ef}
T3	1.0^{e}	2.7^{d}	5.3^{b}	7.3^{cd}	T3	4.29^{a}	0.98^{a}	261^{cd}	16.51^{e}	150^{f}	1.85^{de}
T4	17^{cde}	3.7^{cd}	6.3^{ab}	8.3^{bcd}	T4	4.22^{bc}	0.62^{c}	279^{cd}	17.19^{d}	154^{e}	2.12^{bc}
T5	2.7^{abc}	5.7^{ab}	9.3^{a}	13.0^{a}	T5	4.24^{b}	0.95^{ab}	395^{a}	20.63^{c}	162^{c}	1.96^{cd}
T6	3.7^{a}	4.7^{bc}	9.0^{a}	11.7^{ab}	T6	4.13^{d}	0.82^{b}	285^{c}	25.08^{a}	159^{cd}	1.27^{g}
T7	2.3^{bcd}	4.3^{bcd}	8.3^{a}	11.3^{ab}	T7	4.10^{d}	0.97^{a}	366^{b}	23.22^{b}	148^{f}	2.16^{bc}
T8	3.0^{ab}	3.7^{cd}	6.7^{ab}	10.7^{abc}	T8	4.24^{b}	0.87^{ab}	383^{ab}	25.00^{a}	159^{cd}	2.44^{a}
T9	2.0^{bcde}	6.3^{a}	7.0^{ab}	9.7^{abcd}	T9	4.14^{d}	0.88^{ab}	256^{d}	17.28^{d}	157^{de}	2.35^{ab}
CD($P \leq 0.05$)	0.7	0.9	1.6	1.8	CD($P \leq 0.05$)	0.03	0.07	15.3	0.29	1.97	0.13

SOC=Soil organic carbon; Avail. N=Available nitrogen (kg ha^{-1}); Avail. P=Available phosphorus (kg ha^{-1}); Avail. K=Available potassium (kg ha^{-1}) and Zn=Available zinc. (Within a column, figures with same letters do not differ significantly at $P \leq 0.05$).

The total dry biomass yield under the field experiment (Table 3) was found to range from 2.21 t ha^{-1} to a maximum of 3.87 t ha^{-1} and found to be insignificant between the treatments ($P \leq 0.05$). The pod yield was found significantly higher in the treatments T5 (2.28 t ha^{-1}), T7 (2.26 t ha^{-1}) and T8 (2.23 t ha^{-1}) treatments. The maximum seed yield of 1.56 t ha^{-1} was observed in the treatments T5 and T7 (1.56 t ha^{-1}) (Table 3). In the present experiment after observing the crop growth and yield parameters it can be concluded that the treatment T5 and T7 performed best in terms of nodulation and seed yield which explains that in acid soil the native isolates of *Rhizobium* play a very important role in the number of nodules formed and when it was combined with the enriched compost having native *Rhizobium* (NR2) in it nodulation is enhanced.

Soil nutrient availability under lentil crop in field experiment

Soil pH (Table 1) before crop and after the harvest of crop does not differ significantly under most of the treatments. In treatments T1, T3, T5, T8 and T2, soil pH was found to increase after the harvest of crop. SOC significantly increased ($P \leq 0.05$) under the treatments T7 and T3. Available nitrogen content significantly increased in all the treatments except T2 (174 kg ha^{-1}). Available zinc was also found to increase after the harvest of the crop and T8 (2.44 ppm) observed significantly higher content in Zn. Available potassium in the soil decreases in all the treatments after the harvest of the lentil crop. The increased in available N content after the harvest of the crop is due to the N_2 fixation in field experiment under treatments with *Rhizobium* seed inoculation along with the *Rhizobium* compatible enriched compost application. The similar results were reported by Muhammad (2011). The lower available N in T2 treatment might have been caused by limited fertilizer application with no organic manures, uptake by plants, leaching and denitrification process. Significantly higher available phosphorus observed in T6 and T8. The observed high soil available phosphorus values in the present experiment after the harvest of the lentil crop explained that the phosphorus addition in the form of inorganic fertilizer and in enriched compost satisfied the phosphate demand by biological nitrogen fixation as well as for the yield of the lentil crop (Weria *et al.,* 2013).

Soil enzymes play a vital role in nutrient mineralization and their activity is an excellent sensor in predicting the capacity of nutrient supply to plants (Akmal *et al.,* 2012). Dehydrogenase (DHA) enzyme oxidizes soil organic matter by transferring protons and electrons from substrates to acceptors and is considered as an indicator of overall microbial activity because it occur intracellularly in all living microbial cells and is linked with microbial oxide-reduction processes (Stepniewska and Wolinska, 2005). The dehydrogenase activity (DHA) was observed (Fig 2) significantly higher ($P \leq 0.05$) in the treatments T7 {18.45 µg (TPF) g^{-1} (dw) soil h^{-1}}. Enzyme phosphatases play an essential role in the cycling and availability of soil

Table 2: Number of nodules and nodules fresh weight at 30 days interval of lentil crop.

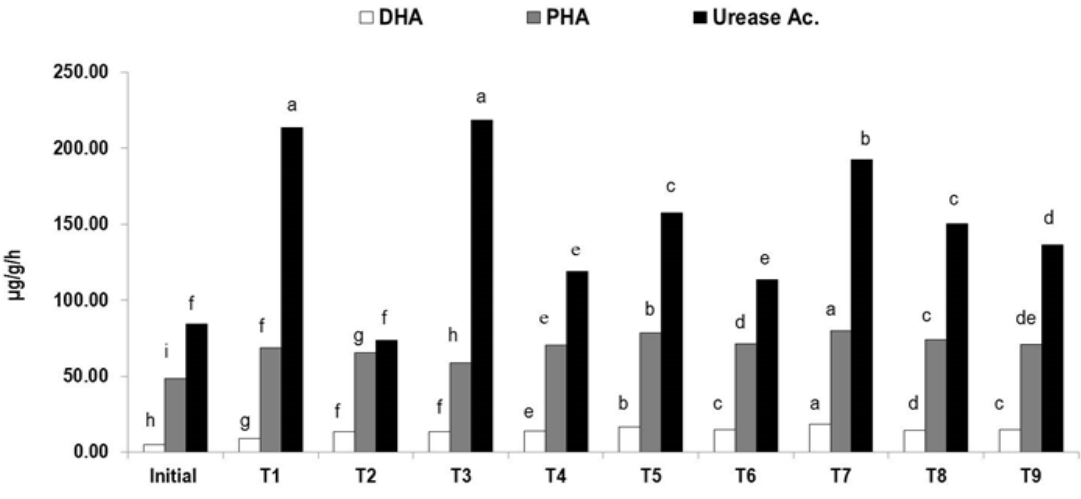
Treatment	Total no. of nodules				Nodules fresh weight (mg)			
	30 days	60 days	90 days	120 days	30 days	60 days	90 days	120 days
T1	0	2.33	3.67^{c}	12.67^{c}	0	2.93^{b}	10.05^{bcd}	3.83^{c}
T2	0	1.33	2.00^{c}	19.00^{c}	0	10.17^{b}	18.50^{bc}	23.23^{ab}
T3	4.67^{b}	10.67	10.67^{bc}	38.00^{bc}	2.45^{bc}	13.85^{b}	6.25^{cd}	10.83^{abc}
T4	0.33^{cd}	5.67	23.33^{ab}	26.33^{bc}	0.30^{d}	9.77^{b}	5.90^{cd}	4.33^{bc}
T5	7.67^{a}	17.00	18.33^{abc}	79.00^{a}	1.05^{cd}	4.70^{b}	3.25^{d}	5.96^{abc}
T6	3.00^{bc}	5.33	23.67^{ab}	38.33^{bc}	2.45^{bc}	4.25^{b}	13.10^{bcd}	9.40^{abc}
T7	2.33^{bcd}	8.00	19.67^{abc}	60.00^{ab}	5.40^{a}	41.00^{a}	34.25^{a}	24.50^{a}
T8	3.00^{bc}	5.67	7.67^{bc}	25.67^{bc}	3.25^{b}	6.15^{b}	21.90^{b}	4.93^{bc}
T9	4.67^{b}	6.67	35.67^{a}	27.67^{bc}	1.05^{cd}	2.40^{b}	10.20^{bcd}	6.63^{abc}
CD (P≤0.05)	1.44	NS	10.12	19.60	0.99	6.55	7.12	9.81

Within a column, figures with same letters do not differ significantly at P≤0.05.

Table 3: Leaf area and leaf area index at 30 days interval up to 90 days and plant yield parameters at the harvest.

Treatment	Leaf area (cm^2)			LAI			Total dry biomass yield	Pod yield	Seed yield
	30 days	60 days	90 days	30 days	60 days	90 days		(t ha^{-1})	
T1	35.69^{bcd}	118.28^{bcd}	195.88^{cd}	0.45^{abc}	1.51^{bcd}	2.50^{cd}	3.01	1.92^{ab}	1.26^{b}
T2	34.45^{bcd}	125.33^{bcd}	183.02^{de}	0.44^{abc}	1.60^{bcd}	2.33^{de}	2.21	0.98^{d}	0.83^{c}
T3	25.73^{cd}	117.03^{cde}	221.61^{bc}	0.33^{bc}	1.49^{cde}	2.82^{bc}	2.40	1.37^{cd}	1.02^{c}
T4	24.90^{d}	107.07^{de}	149.40^{e}	0.32^{c}	1.36^{de}	1.90^{e}	2.93	1.90^{ab}	1.39^{ab}
T5	63.91^{a}	169.32^{a}	243.19^{ab}	0.81^{a}	2.16^{a}	3.10^{ab}	3.87	2.28^{a}	1.56^{a}
T6	34.86^{bcd}	134.88^{bc}	201.69^{cd}	0.44^{abc}	1.72^{bc}	2.57^{cd}	3.03	1.78^{abc}	1.35^{ab}
T7	39.43^{b}	144.84^{b}	264.36^{a}	0.50^{b}	1.85^{ab}	3.37^{a}	3.36	2.26^{a}	1.55^{a}
T8	39.01^{bc}	131.97^{bcd}	216.63^{bcd}	0.50^{b}	1.68^{bcd}	2.76^{bcd}	3.07	2.23^{a}	1.42^{ab}
T9	35.28^{bcd}	91.72^{e}	212.90^{bcd}	0.45^{abc}	1.17e	2.71^{bcd}	2.46	1.52^{bc}	0.97^{c}
CD (P≤0.05)	6.99	14.21	16.99	0.09	0.18	0.25	NS	0.27	0.12

LAI= Leaf area index. Within a column, figures with same letters do not differ significantly at P≤0.05.



Dehydrogenase activity (DHA), acid-phosphomonoasterase activity and urease activity under treatments and CD (P≤0.05)= 0.13, 0.45 and 7.50 respectively. Within a column, figures with same letter do not differ significantiy at P≤0.05.

Fig 2: Enzyme activities at 60 days of crop growth under the field experiment.

phosphorus in soil and they occur either extracellularly or within the living cell and their sources are the soil microbial community as well as plant roots and residues. The phosphatase activity (PHA) was observed significantly higher in the treatment T7 {79.94 µg p-nitrophenol g^{-1} (dw) soil h^{-1}}. For all the enzyme activities the lower values were observed before the lentil crop was grown. Juma and Tabatabai (1978) reported that acid phosphatase (PHA) is predominant in acid soils and that alkaline phosphatase is predominant in alkaline soils. In present experiment also high amount of acid phosphatases were observed in almost all the treatments under study. This might as well be due to the application of higher doses of P fertilizers as well as the high content of P in the enriched compost. Enzyme urease is an extracellular enzyme involved in the hydrolysis of urea-type substrates and its activity is important in the transformation of urea fertilizer. Urease activity was recorded significantly higher in the treatments T3 (224 µg NH_4 released g^{-1} soil hr^{-1}) and T8 (213.5 µg NH_4 released g^{-1} soil hr^{-1}). Both DHA and urease enzymes were higher in treatments receiving seed inoculation, enriched compost and inorganic fertilizers treated plots and Akmal *et al.* (2012) also reported the similar results and stated that organic matter and N and P fertilizers often has the direct effect on the activity of various enzymes.

CONCLUSION

In acid soils the excess amount of H^+, Al^{3+} and deficiency of P affects the crop by limiting the root growth and in turn nutrient absorption and ultimately, affecting severely the crop productions. So, resource manipulations and remedial measures play a very important role in these regions for effective crop productivity. The addition of *Rhizobium* compatible enriched compost on lentil crop along with the seed inoculation had a various positive effect in the present experiment under field conditions. Soil pH was found to increase in treatments *viz*. T1, T3, T5, T8 and T2. SOC significantly increased ($P \leq 0.05$) under the treatments T7 and T3 after the harvest of the lentil crop. Available nitrogen and available phosphorus content significantly increased in almost all the treatments after the harvest of the crop. The experiment even though was conducted in the strongly acidic soils with pH 4.11, the initial crop growth of the lentil plant performed well by attaining a medium height, good nodulations and yield as well as maintaining the soil fertility.

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Disclaimers

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Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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