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Variation in Chemical properties of Soil after Harvest of Malt Barley Crop (*Hordeum vulgare* L.) under different Fertility Levels and Biofertilizers in Sub Tropical Southern Plains and Aravali Hills of Rajasthan

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ABSTRACT: Soil is the important component of crop production, has numerous functions and vital role in production system. Indiscriminate use of inorganic fertilizers is the major cause for soil salinization, alkalization and soil acidity which ultimately affects the crop yield. To overcome such problems, during the *rabi* season 2020–21 and 2021–22, a field trial was carried out at the Instructional Farm, Department of Agronomy, Rajasthan College of Agriculture, MPUAT, Udaipur on clay loam soil with low available nitrogen (278.36 to 279.42 kg ha^{-1}), medium available phosphorus (18.73 to 20.39 kg ha^{-1}) and high available potassium status (328.40 to 332.72 kg ha^{-1}) which was slightly alkaline in response with 15 treatment combinations made up of three fertility levels- 50 kg N + 25 kg P_2O_5 + 15 kg K_2O ha^{-1}, 60 kg N+30 kg P_2O_5 + 20 kg K_2O ha^{-1} and 70 kg N + 40kg P_2O_5 + 25 kg K_2O ha^{-1} with five biofertilizers *i.e.* control, *Azotobacter*, PSB, KMB and *Azotobacter* + PSB + KMB. The trial was set up in a randomised block design (factorial).As a result of the investigation, after the harvesting of crop, application of 70 kg N+40 kg P_2O_5 + 25 kg K_2O ha^{-1} recorded maximum available nitrogen (299.18 kg ha^{-1}), available phosphorus (25.57 kg ha^{-1}), available potassium (349.80 kg ha^{-1}) and organic carbon (0.708 %) in soil which was significantly higher over remaining fertility levels. Further, the results showed that seed inoculation with liquid biofertilizers *Azotobacter* + PSB + KMB significantly enhanced available nitrogen (304.97 kg ha^{-1}), available phosphorus (25.09 kg ha^{-1}) and available potassium (357.44 kg ha^{-1}) in soil after harvest of crop.

Thus, the combine application of 70 kg N + 40 kg P_2O_5 + 25 kg K_2O ha^{-1} along with inoculation of seed with *Azotobacter* + PSB + KMB proved most effective in elevating nutrient status of soil.

Keywords: Malt barley, available nutrients, biofertilizers and fertility levels.

INTRODUCTION

Barley is largely cultivated on marginal and sub-marginal land due to its low input needs. The northern plains of India, specifically the states of Uttar Pradesh, Haryana and Rajasthan are the major barley growing regions. In India, barley was grown on 610.5 thousand ha area, producing 1600 thousand tonne with an average productivity of 26 q ha^{-1}. With more than 52% of the nation's production and 46% of its total area, Rajasthan is India's leading state, followed by Uttar Pradesh. In Rajasthan, the area under the cultivation of barley is 312.7 thousand ha with 1059.3 thousand t of production at an average productivity of 33.88 q ha^{-1} (IIWBR, 2020-21).With rising beer consumption, the use of two-rowed barley for the malting and brewing industries has increased recently (Gupta *et al.,* 2010). Presently about 20-25% of total barley production is used for the preparation of malt for brewing, distillation, baby foods, confectionaries cocoa- malt drink and medicinal syrups. One of the most crucial prerequisites in this regard is adequate mineral fertilization. The increase in yield is not encouraging despite the application of the recommended amounts of the major nutrients. The most vital nutrient for plant growth and development is nitrogen. It is a crucial component of chlorophyll, which is necessary for photosynthesis (Jat, 2021). Phosphorus is essential for plant metabolism. Being a component of DNA and RNA, it allows the conversion and transmission of genetic information and ensures the transfer and storage of energy as ADP and ATP. Potassium regulates cell membrane, maintains hydration in the protoplasm and contribute to its significant role in the maintenance of cellular organisms. Alternatively, biofertilizers play a very important role in increasing soil fertility by fixing atmospheric nitrogen both in association with and without plant roots, solubilizing insoluble soil phosphates and producing plant growth substances in the soil and solubilizing inorganic potassium from insoluble compounds and making it available for plant uptake.The favorable effect of combined inoculation of *Azotobacter,* PSB and KMB could be attributed to synergistic interaction among phosphate solubilizing, potash mobilizing microorganism and free living organism, which lead to increased availability of nutrients (Khatkar *et al*., 2007). Now it is indeed to promote the integrated use of biofertilizer with chemical fertilizer to minimize the dependence on inorganic fertilizer alone. Therefore, keeping in view of above facts the present study has been conducted.

MATERIAL AND METHODS

At the Instructional Farm, Department of Agronomy, Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan, the field trial was carried out during the *rabi* seasons of 2020–2021 and 2021–2022. The soil of the trial field had a clay loam texture, reacted slightly alkaline, low in available nitrogen, medium in available phosphorus and high in available potassium status. The trial was conducted in randomized block design (Factorial) with 15 treatment combinations made up of three fertility levels- 50 kg N+25 kg P_2O_5 +15 kg K_2O ha^{-1}, 60 kg N+30 kg P_2O_5 +20 kg K_2O ha^{-1} and 70 kg N+40kg P_2O_5 +25 kg K_2O $ha^{-1}$with five biofertilizers *i.e.* control, *Azotobacter*, PSB, KMB and *Azotobacter*+ PSB + KMB. Prior to seeding, full phosphorus and potassium and half nitrogen were drilled into the furrows. At the time of the first irrigation, the remaining half dose of the nitrogen were top dressed on the crop. In accordance with standard procedure, the seeds were treated with liquid biofertilizers using 5 ml per kg of seed, 2-3 hours prior to sowing. Using a seed rate of 100 kg per hectare and a row spacing of 20 cm, the seeds were sown in a furrow that was opened at a depth of about 4-5 cm. Following crop harvest, soil samples were collected from each plot at a depth of 0 to 15 cm. According to the procedures listed in Table 1, the samples were examined for pH, EC, organic carbon, nitrogen, phosphorus and potassium.

Table 1: Physico-chemical properties of experimental field.

	Soil properties	Contents		Method adopted
		2020-21	2021-22	
A.	**Mechanical composition**			
(i)	Sand (%)	37.23	37.46	International pipette method (Piper, 1950)
(ii)	Silt (%)	26.56	26.75	
(iii)	Clay (%)	34.37	34.92	
(iv)	Textural class	Clay loam	Clay loam	Triangular diagram (Brady and Weil 2003)
B.	**Physical composition**			
(i)	Bulk density (Mg m^{-3})	1.43	1.41	Core sampler method (Piper, 1950)
(ii)	Particle density (Mg m^{-3})	2.46	2.54	Black (1965)
(iii)	Porosity (%)	41.87	44.48	Black (1965)
C.	**Chemical composition**			
(i)	Organic carbon (%)	0.61	0.63	Walkley and Black (1934)
(ii)	Available nitrogen (kg ha^{-1})	278.36	279.42	Alkaline $KMnO_4$ method (Subbiah and Asija 1956)
(iii)	Available phosphorus (kg ha^{-1})	18.73	20.39	Olsen's method (Olsen *et al.*, 1954)
(iv)	Available potassium (kg ha^{-1})	328.40	332.72	Flame photometer method (Jackson, 1973)
D.	**Physic-chemical**			
(i)	Electrical conductivity (dSm^{-1} at 25° C)	0.51	0.53	Conductivity bridge (Richards, 1968)
(ii)	pH (1:2.5 soil: water)	7.96	8.01	Blackman's pH meter (Piper, 1950)

RESULT AND DISCUSSION

The physic-chemical properties of soil after harvest of malt barley crop due to the effect of various treatments are mentioned in Table 2 and 3.

pH and Electrical conductivity (dSm^{-1}). Fertility levels and liquid biofertilizers failed to exhibit significant effect on pH and electrical conductivity of soil after harvesting of crop (Table 2).

Organic carbon(%)

Fertility levels. The application of 70 kg N+40 kg P_2O_5 +25 kg K_2O ha^{-1} to malt barley crop recorded significantly higher organic carbon content of soil after crop harvest over application of 60 kg N+30 kg P_2O_5+20 kg K_2O ha^{-1} and 50 kg N+25 kg P_2O_5+15 kg K_2O ha^{-1} during both years. On pooled basis, application of 70 kg N+40 kg P_2O_5 +25 kg K_2O ha^{-1} significantly improved organic carbon content of soil after crop harvest by5.67 and 12.91 per cent over application of 60 kg N+30 kg P_2O_5+20 kg K_2O ha^{-1} and 50 kg N+25 kg P_2O_5+15 kg K_2O ha^{-1}, respectively (Table 2).

Due to higher biomass and a different rate at which organic matter is oxidised by microbes when fertilizer is applied, organic carbon content of soil is improved. Alike findings were also observed by several researchers (Dhonde and Bhakar 2008; Chavarekar *et al.,* 2013; Parewa *et al*., 2014).

Liquid bio-inoculants. Data reveals that during both the study years and on pooled basis, the application of liquid biofertilizers did not influence the organic carbon content of the soil after crop harvest.

Available nitrogen

Fertility levels. An analys is of data (Table 3) discloses that fertility levels exhibited significant influence on available nitrogen status of soil after harvest of malt barley crop during both study year's and in pooled analysis. Maximum availability of nitrogen in soil after crop harvest was recorded with the application of 70 kg N+40 kg P_2O_5 +25 kg K_2O ha^{-1}which was significantly higher over application of 60 kg N+30 kg P_2O_5+20 kg K_2O $ha^{-}$and 50 kg N+25 kg P_2O_5+15 kg K_2O ha^{-1} during both years.

The pooled data show that use of 70 kg N+40 kg P_2O_5 +25 kg K_2O ha^{-1}(299.18 kg ha^{-1}) significantly improved available nitrogen status of soil after crop harvest by 3.46 and 7.68 per cent over application of 60 kg N+30 kg P_2O_5+20 kg K_2O ha^{-1}(289.15kg ha^{-1}) and 50 kg N+25 kg P_2O_5+15 kg K_2O ha^{-1}(277.83 kg ha^{-1}), respectively.

Increased nitrogen-fixing bacterial activity may be responsible for the significant increase in soil nitrogen availability and subsequent increase in soil nitrogen accumulation Parmer *et al*. (1998); Kumavat *et al.* (2016); Kumar (2019).

Liquid biofertilizers. The nitrogen status of soil was significantly influenced by malt barley seed inoculated with liquid biofertilizers alone and in combination during two years of investigation and on pooled basis. The pooled results indicate that inoculation with *Azotobacter*, PSB, KMB alone and in combination of *Azotobacter* + PSB + KMB significantly improved available nitrogen status of soil after crop harvestby7.48, 6.41, 4.80 and 12.41 per cent over control, respectively. Among liquid biofertilizers, co inoculation with *Azotobacter* + PSB + KMB estimated maximum available nitrogen in soil over single inoculation of *Azotobacter*, PSB and KMB during both years. On an average, significant improvement in available nitrogen status of soil due to inoculation with liquid biofertilizers *Azotobacter* + PSB + KMB (304.97 kg ha^{-1})was4.33, 5.38 and 7.00 per cent over sole inoculation of *Azotobacter*, PSB and KMB, respectively.

Available phosphorus

Fertility levels. The crop under the influence of70 kg N+40 kg P_2O_5 +25 kg K_2O ha^{-1} recorded maximum phosphorus status of soil after crop harvest which was significantly superior over remaining fertility levels during both years (Table 3). Pooled results indicate that the magnitude of increases in phosphorus status of soil after crop harvest with fertilization of 70 kg N+40 kg P_2O_5 +25 kg K_2O ha^{-1}(25.57 kg ha^{-1}) was to the tune of 12.79 and 24.12 per cent over application of 60 kg N+30 kg P_2O_5+20 kg K_2O ha^{-1}(22.67 kg ha^{-1}) and 50 kg N+25 kg P_2O_5+15 kg K_2O ha^{-1} (20.60 kg ha^{-1}), respectively.

Due to limited ability of crop to utilise the phosphorus from the applied source, phosphorus status of soil increased with increasing fertility levels Prasad (1994); Kumavat *et al.* (2016); Malik (2018).

Liquid biofertilizers. A reference to data indicates that during both the study years and in the pooled analysis, inoculating malt barley seed with liquid biofertilizers alone and in combination significantly improved the available phosphorus status of soil after crop harvest. The significant improvement in mean available phosphorus status of soilafter crop harvest was to the tune of 11.31, 14.07, 9.80 and 21.79 per cent, respectively with the application of *Azotobacter*, PSB, KMB alone and in combination of *Azotobacter* + PSB + KMB over control. Among liquid biofertilizers, inoculation with liquid biofertilizer consisted combination of *Azotobacter* + PSB + KMB (25.09 kg ha^{-1}) recorded highest available phosphorus status of soil after crop harvest was significantly higher over separate inoculation of *Azotobacter*, PSB and KMB during both years. Thus when linked to inoculation with *Azotobacter*, PSB and KMB alone, combined application with biofertilizer *Azotobacter* + PSB + KMB significantly enhanced mean phosphorus status of soil by 9.41, 6.76 and 10.91 per cent, respectively.

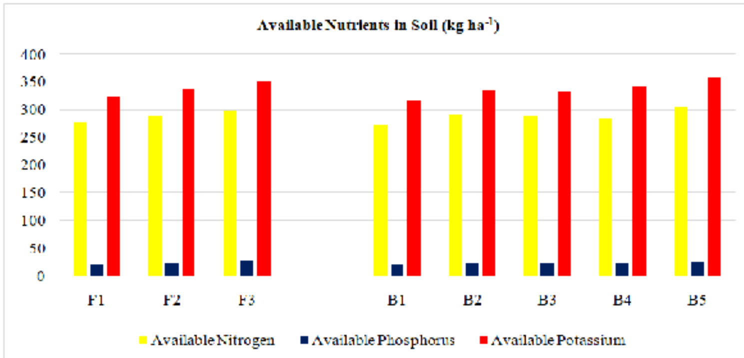
Available potassium

Fertility levels. Application of 70 kg N+40 kg P_2O_5 +25 kg K_2O ha^{-1}recorded maximum available potassium in soil which was significantly higher over application of 60 kg N+30 kg P_2O_5+20 kg K_2O ha^{-1} and 50 kg N+25 kg P_2O_5+15 kg K_2O ha^{-1} during both years (Table 3). Thus when compared to application of 60 kg N+30 kg P_2O_5+20 kg K_2O ha^{-1}(337.24 kg ha^{-1}) and 50 kg N+25 kg P_2O_5+15 kg K_2O ha^{-1} (323.91 kg ha^{-1}), application of 70 kg N+40 kg P_2O_5 +25 kg K_2O ha^{-1} (349.80 kg ha^{-1}) significantly enhanced available potassium status of soil after crop harvest to the extent of 3.72 and 8.00 per cent, respectively.

The increased potassium status could be attributed to higher potassium addition through muriate of potash may be responsible for the improved potassium status. The same trend were observed by El-Hamid *et al.*(2013); Malik *et al.* (2019).

Liquid biofertilizers. During both study years and in pooled analysis, inoculation of malt barley seed with liquid biofertilizers alone and in combination significantly improved available potassium status of soil. The significant improvement in mean available potassium status in soil with seed inoculation with liquid biofertilizers *Azotobacter*, PSB, KMB alone and in combination *Azotobacter* + PSB + KMB was to the extent of 6.32, 5.14, 8.04 and 12.96 per cent, respectively. Among liquid biofertilizers, combined application of *Azotobacter* + PSB + KMB recorded maximum available potassium status of soilafter crop harvest which was significantly higher over separate inoculation of *Azotobacter*, PSB and KMB during two years. On pooled basis, combined treatment of seed with *Azotobacter* + PSB + KMB (357.44 kg ha^{-1}) significantly enhanced available potassium status of soil after crop harvest by 6.23, 7.43 and 4.54 per centover single inoculation of *Azotobacter*, PSB and KMB, respectively.

Biofertilizers consists of living cells of efficient strains of various microorganism (bacteria, algae and fungi) which play a number of pivotal roles in soil fertility and ability to extract nutritionally essential components from inaccessible forms. Results described in preceding chapter showed that liquid biofertilizers were found ineffective in term of altering the soil pH, EC and organic carbon during both years. Co inoculation of *Azotobacter* + PSB + KMB was found most effective in terms of increasing the availability of nitrogen, phosphorus and potassium status in soil. In contrast to *Azotobacter*, which can transform atmospheric nitrogen into a form that is readily available in the soil, PSB secrete some organic acids that can solubilize phosphorus from insoluble and fixed forms to plant-available forms. KMB solubilizes silicate minerals and discharges potassium through the formation of organic and inorganic acids, acidolysis, chelate formation and ion exchange (Mane *et al.* 2014; Me Carty *et al.* 2017). However, the release of growth-stimulating hormones, the management of plant pathogens and the proliferation of advantageous organisms in the rhizosphere are a few other factors that may contribute to the increase in yield brought about by biofertilizer inoculation which helps in nitrogen fixation, phosphorus solubilization and potassium mobilisation. These findings closely align with the findings of Jat (2021); Jatinderpal (2021).



Where, F1- 50 kg N+25 kg P_2O_5 +15 kg K_2O ha^{-1}; F2-60 kg N+30 kg P_2O_5 + 20 kg K_2O ha^{-1}; F3-70 kg N+40 kg P_2O_5 +25 kg K_2O ha^{-1}; B1- Control; B2- *Azotobacter*; B3- PSB ; B4- KMB ; B5- *Azotobacter* + PSB + KMB

Fig. 1. Effect of fertility levels and biofertilizers on available nutrients (kg ha^{-1}) of soil after harvest of malt barley.

Table 2: Effect of fertility levels and biofertilizers on chemical properties of soil after harvest of malt barley.

Treatments	pH			EC (dSm^{-1})			Organic carbon (%)		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Fertility levels									
50 kg N+25 kg P_2O_5+15 kg K_2O ha^{-1}	7.65	7.64	7.64	0.491	0.501	0.496	0.614	0.640	0.627
60 kg N+30 kg P_2O_5+20 kg K_2O ha^{-1}	7.67	7.68	7.67	0.495	0.514	0.504	0.659	0.682	0.670
70 kg N+40 kg P_2O_5+25 kg K_2O ha^{-1}	7.69	7.70	7.69	0.516	0.531	0.523	0.702	0.715	0.708
S.Em.$\pm$	0.06	0.06	0.04	0.014	0.011	0.009	0.014	0.010	0.009
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	0.040	0.029	0.024
Liquid biofertilizers									
Control	7.64	7.64	7.64	0.474	0.479	0.477	0.632	0.650	0.641
Azotobacter	7.68	7.69	7.69	0.507	0.521	0.514	0.665	0.683	0.674
PSB	7.66	7.67	7.67	0.504	0.518	0.511	0.662	0.680	0.671
KMB	7.65	7.66	7.66	0.509	0.520	0.515	0.667	0.682	0.675
Azotobacter + PSB + KMB	7.70	7.70	7.70	0.509	0.538	0.524	0.665	0.700	0.683
S.Em.$\pm$	0.07	0.08	0.05	0.019	0.014	0.012	0.018	0.013	0.011
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 3: Effect of fertility levels and biofertilizers on available nutrient status of soil after harvest of malt barley.

Treatments	Nitrogen (kg ha^{-1})			Phosphorus (kg ha^{-1})			Potassium (kg ha^{-1})		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Fertility levels									
50 kg N+25 kg P_2O_5+15 kg K_2O ha^{-1}	276.55	279.11	277.83	20.35	20.85	20.60	323.31	324.52	323.91
60 kg N+30 kg P_2O_5+20 kg K_2O ha^{-1}	287.14	291.15	289.15	22.42	22.91	22.67	336.57	337.92	337.24
70 kg N+40 kg P_2O_5+25 kg K_2O ha^{-1}	297.89	300.47	299.18	25.33	25.82	25.57	349.04	350.56	349.80
S.Em.$\pm$	3.12	3.03	2.18	0.37	0.34	0.25	3.77	3.45	2.56
C.D. (P=0.05)	8.91	8.65	6.12	1.05	0.96	0.70	10.76	9.85	7.19
Liquid biofertilizers									
Control	269.20	274.69	271.94	20.35	20.85	20.60	315.66	317.21	316.43
Azotobacter	291.13	293.47	292.30	22.68	23.18	22.93	335.74	337.16	336.45
PSB	288.14	290.63	289.39	23.25	23.75	23.50	331.78	333.64	332.71
KMB	283.77	286.24	285.00	22.43	22.82	22.62	341.13	342.65	341.89
Azotobacter + PSB + KMB	303.74	306.20	304.97	24.80	25.37	25.09	357.23	357.66	357.44
S.Em.$\pm$	4.03	3.91	2.80	0.47	0.44	0.32	4.87	4.46	3.30
C.D. (P=0.05)	11.50	11.16	7.89	1.36	1.25	0.91	13.90	12.72	9.28

CONCLUSION

It could be concluded that application of 70 kg N+40 kg P_2O_5 +25 kg K_2O ha^{-1} along with inoculation of seed with liquid biofertilizers *Azotobacter* + PSB + KMB proved to be most suitable practice in elevating the soil chemical properties after harvest of malt barley crop.

FUTURE SCOPE

Extensive investigations are needed on soil physical and chemical factors that may influence rhizosphere and the expression of its traits for benefitting the crop and there is a need of screening effective and low cost liquid biofertilizers in combination with appropriate rate of fertilizer application.

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Conflicts of Interest. None

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