International Journal of Plant & Soil Science

Volume 34, Issue 24, Page 369-374, 2022; Article no.IJPSS.95006
ISSN: 2320-7035

Effect of Different Levels of Arbuscular Mycorrhiza and Phosphorus on Productivity and Profitability of Barley (*Hordeum vulgare* L.)

Bimlesh Kumar Prajapati [a#*], Kaushal Kumar [a†], Munish Kumar [a†], Deepak Kumar Rawat [b‡], Yogesh Kumar [a#], Gaurav Pratap Singh [a‡], Pradeep Kumar [a‡] and Sunil Kumar Prajapati [c#]

[a] *Department of Soil Conservation and Water Management, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, (U.P.)-208002, India.*
[b] *Department of Crop Physiology, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, (U.P.)-208002, India.*
[c] *Department of Agronomy, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, (U.P.)-208002, India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2022/v34i242652

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/95006

Original Research Article

Received: 18/10/2022
Accepted: 23/12/2022
Published: 28/12/2022

[#] *M.Sc. (Ag.);*
[†] *Professor;*
[‡] *Ph.D. Scholar;*
**Corresponding author: E-mail: kumarbimlesh125@gmail.com;*

ABSTRACT

A field experiment was carried out at Soil Conservation and Water Management Farm of Chandra Shekhar Azad University of Agriculture and Technology, Kanpur during *rabi* season, in 2019-20 to study the effect of different levels of Arbuscular Mycorrhiza (AM) and phosphorus on yield attributes, yield and economics of barley (*Hordeum vulgare* L.). The experiment was laid out in Factorial Randomized Block Design (FRBD) with 3 replications. The treatments were consisted of 4 levels of AM fungi inoculation i.e., control**,** AM @ 8 kg ha^{-1}, AM @ 12 kg ha^{-1} and AM @ 16 kg ha^{-1} along with 4 phosphorus fertility level i.e., control**,** phosphorus @ 20 kg ha^{-1}**,** phosphorus @ 30 kg ha^{-1} and phosphorus @ 40 kg ha^{-1} were tested in the experiment. The results indicated that the AM fungi inoculation level @ 16 kg ha^{-1} showed the highest yield attributes, yield and economics *viz*. number of productive tillers (9.03 m^{-2}), number of grain ear^{-1} (9.16), test weight (45.36g), grain yield (28.13 q ha^{-1}), gross return (INR 45774.20 ha^{-1}), net return (INR 18143.04 ha^{-1}) and B:C ratio (1.66) followed by the AM fungi inoculation level @ 12 kg ha^{-1} while it was observed minimum under control. However, the phosphorus fertility level @ 40 kg ha^{-1} gave better yield attributes, yield and economics *viz*., number of productive tillers (9.16 m^{-1}), number of grain ear^{-1} (59.36), test weight (45.09g), grain yield (28.79), gross return (INR 47377.60 ha^{-1}), net return (INR 18229.50 ha^{-1}) and B:C ratio (1.63) followed by the phosphorus fertility level @ 30 kg ha^{-1} while observed minimum under control. On the basis of observed results, farmers are advised to raise barley with AM fungi inoculation level @ 16 kg ha^{-1} along with application of phosphorus @ 40 kg ha^{-1} for best growth, yield, economics and soil health.

Keywords: Barley; Arbuscular Mycorrhiza (AM); phosphorous; yield attributes; yield; profitability.

1. INTRODUCTION

"Barley (*Hordeum vulgare* L.) is the world´s fourth most important cereal crop after wheat, rice and maize and the most dependable crop in alkali soils and areas where frost or drought occurs" [1]. "The major barley producing countries are China, Russia, Germany, USA, Canada, India, Turkey and Australia. The major use of barley grain is in brewing industries for manufacturing malt which is used to make beer, industrial alcohol, whisky, malt syrups, brandy, malted milk, vinegar and yeast" [2].

In India, barley is mainly grown in the northern plains and concentrates in the states of Rajasthan, Haryana, Punjab and western UP. Among the various constraints of its lower productivity in the arid and semiarid regions due to the erratic nature of the climate, poor quality of irrigation water, inadequate fertilization, poor soil physical conditions, nutrient imbalances and deficiencies of some macro and micronutrients. Besides these course texture of the soil, poor organic matter content, low water receptivity, excessive permeability and a sharp increase in soil strength upon drying are also important factors associated with low production.

"Mycorrhizal fungi can form a symbiosis with field crops under a range of environmental conditions" [3]. "This symbiosis can enhance nutrient uptake and plant growth under various environmental stress conditions such as salinity, drought and low fertility. The beneficial effect of mycorrhizae on plant growth was attributed to enhanced phosphorus uptake" [4]. "The increase in nutrient uptake is proposed to be due to increased affinity to a particular ion and lowering the threshold concentration for absorption and by exploring greater soil volume and increasing root surface area" [5]. "*Arbuscular mycorrhizal* (AM) fungi can alleviate some of the negative effects of high levels of salts and increase plant tolerance to soil salinity" [6]. "The improved plant nutrition and nutrient balance *via* AM fungi can have a beneficial influence on the salinity and drought tolerance of crops in semiarid regions" [7]. With mycorrhizal hyphae, plants grow faster and with the mycorrhizal hyphae grow more intense and deeper in the soil and water can be therefore, extracted more efficiently. There is also evidence that mycorrhizal plants recover faster from short drought periods than non-mycorrhizal plants.

Nitrogen is universally deficient plant nutrient in most of the Indian soils. Nitrogen is an essential constituent of many compounds such as nucleotides, phospholipids, enzymes, hormones, vitamin and protein nucleic acid and chlorophyll plays a major role in photosynthesis and chlorophyll synthesis [8]. There is a wide gap between production and consumption of N fertilizer and greater emphasis necessarily has to be laid on supplementation and use of chemical fertilizers with renewable and cheaper sources of nutrients *viz*., bio-fertilizers and organics. Hence, an integrated approach is a matter of considerable interest, which gained importance in recent years. “Phosphorus (P) is another important nutrient next to nitrogen. At present 49.3% of the Indian soils are under low category, 48.8% under medium and 1.9% under high category of Phosphorous” [9]. “The Phosphorous input in Indian agriculture comes from fertilizers, organic manures and to a very small extent from crop residues. It is an indispensable constituent of nucleic acid, ADP and ATP. It has beneficial effects on root development, growth and also hastens maturity as well as improves quality of crop produce” [10]. The availability and form of P in the soil depends upon the native and/or added sources of phosphate fertilizer and organic matter content from external sources.

Over use of chemical fertilizers harms the biological power of soil, which must be prevented as all nutrient transformation are negotiated by soil micro flora. Organic matter is the source of energy to the soil micro flora and organic carbon content and it is considered to be index of the soil health [11]. Organic materials are intrinsic and essential component of all soils and make the soil a living dynamic system. Organic matter serves as a reservoir of nutrients that are essential for plant growth. It produces organic acids and CO_2 on decomposition which helps to dissolve minerals and make them more available for the growing plants. It helps to buffer soil against rapid chemical changes and extreme changes in temperature during summer and winter. Organic manures are potential sources of micro nutrient, improves soil structure by providing binding action to soil aggregates, increases water holding and buffering capacity of soils. It also increases nutrient use efficiency by chelating the chemical fertilizer and by preventing losses of nutrients by leaching and other means. The organic supplementation not only a potential sources of NPK and micronutrient but have also been found to be a good substrate for flourishment of microbes resulting into sustained soil productivity [12].

Therefore, keeping in view the above facts the present study with the objectives of, to find out the optimum dose of AM fungi inoculants and phosphorous in barley, to determine the effect of AM fungi on yield attributes and yield of barley, to assess the effect of AM fungi on phosphorus economy and to study the economics of various treatments.

2. MATERIALS AND METHODS

2.1 Experimental Site and Climates

The experiment was carried out during *Rabi* season 2019-20 at Soil Conservation and Water Management farm of Chandra Shekhar Azad University of agriculture and technology is situated in Kanpur, Uttar Pradesh where the experimental field which is located at 26.49^{o} North and 80.29^{o} South. Kanpur district lies between the parallel of $25^{°}$ 26' and $26^{°}$ 58**'** north latitude and $79^{°}$ 31**'** and $80^{°}$ 34**'** east longitude and on an elevation of 129 meter above from the mean sea level. The mean annual rainfall of Kanpur district is about 832 mm which is mainly received during monsoon season from 22nd of June to 1st week of October. The soil of the experimental field was typical Gangetic alluvium representing Kanpur type-1 in texture of normal fertility status.

2.2 Experimental Details

The experiment was laid out in Factorial Randomized Block Design (FRBD) with three replications comprising four AM fungi inoculation level i.e., control**,** AM @ 8 kg ha^{-1}, AM @ 12 kg ha^{-1} and AM @ 16 kg ha^{-1} along with four phosphorus fertility level i.e. control**,** phosphorus @ 20 kg ha^{-1}**,** phosphorus @ 30 kg ha^{-1} and phosphorus @ 40 kg ha^{-1}.

2.3 Cultural Operation

The field was ploughed with a Mouldboard plough and two ploughing with a cultivator followed by planking. Standard dose of nitrogen and potash @ 60, 40 kg ha^{-1} (P_2O_5, K_2O) respectively, was applied as per prescribed methods in the rainfed conditions at the time of sowing. Sowing of barley variety K-603 was done on 03 December, 2019 in furrow opened by Desi plough at 25 cm apart at a depth of 4-5 cm with seed rate of barley @ 75 kg ha^{-1}.

2.4 Observations Recorded

The observed parameters yield attributes, yield and profitability were characterized as Productive tiller (m^{-2}), Number of ear $plant^{-1}$, Number of seeds ear^{-1}, Seed weight $plant^{-1}$, test weight, grain yield, cost of cultivation, gross return, net return and benefit: cost ratio had to be determined. Data obtained was exposed to the proper method for statistical analysis of variance difference among mean of different treatments as described by Gomez and Gomez, [13]. The treatments means were compared using the Least Significant Differences (LSD) test at 5% level of probability by using the Factorial Randomized Block Design (RBD) model as obtained by SPSS (Statistical Product and Service Solutions) Version 10.0, SPSS, Chicago, IL software.

3. RESULTS AND DISCUSSION

3.1 Yield Attributes

The results showed that the higher values of all yield attributes i.e. number of productive tillers m^{-2} (9.03), number of grain $spike^{-1}$ (58.43) and test weight (45.36) were recorded with the application of AM fungi @ 16 kg ha^{-1} followed by AM fungi @ 12 kg ha^{-1}, AM fungi @ 8 kg ha^{-1} and minimum under control (Table 1). Besides, better root-development of AM fungi @ 16 kg ha^{-1} more helpful for utilization of soil moisture during reproductive crop phase for proper formation and development of various yield attributes of barley. These results are in close conformity to the findings of [14] and [15]. Among phosphorous fertility level, the highest yield attributes were recorded under Phosphorus @ 40 kg ha^{-1} followed by Phosphorus @ 30 kg ha^{-1}, Phosphorus @ 20 kg ha^{-1} and the least in control (Table 1). Thus, with these practices plants utilized more soil phosphorus which facilitated the proper development of flowering, ear formation and grain. Improvement in ear size and provided more opportunity for setting of more number of grain and their proper development with highest test weight. These results may very well support by the findings of [16] and [17]. In contrast, to the deficiency of available phosphorus in root zone under control plot restricted the plant growth, development of reproductive organs and finally resulted in decreased yield attributes of barley for the control treatment.

3.2 Yield

The results showed that the application of AM fungi and Phosphorous levels significantly increased grain yield (Table 1) of barley compared with control. The inoculation level, AM fungi @ 16 kg ha^{-1} produced significantly higher gain yield (28.13 q/ha) than AM fungi @ 12 kg ha^{-1}, AM fungi @ 8 kg ha^{-1} and control. These results confirm with the findings of [18] and [19]. Among Phosphorous level, Phosphorus @ 40 kg ha^{-1} produced significantly higher gain yield followed by Phosphorus @ 30 kg ha^{-1}, Phosphorus @ 20 kg ha^{-1} and the lowest in control. Grain yield might be attributed to various yield attributes i.e. number of ear m^{-2}, number of

Table 1. Effect of different levels of AM fungi and phosphorus on yield attributes and yields under different treatments

Treatments	Productive tiller (m^{-2})	No. of grains $spike^{-1}$	1000- grain weight (g)	Grain yield (q ha^{-1})
A. Inoculation level:				
I_1 : Control	7.45	52.55	40.34	24.32
I_2 : AM fungi @ 8 kg ha^{-1}	8.45	55.34	42.56	25.65
I_3 : AM fungi @ 12 kg ha^{-1}	8.67	56.21	43.45	27.34
I_4 : AM fungi @ 16 kg ha^{-1}	9.03	58.43	45.36	28.13
SE (d)	0.17	0.56	0.29	0.64
CD (P=0.05)	0.39	1.06	0.67	1.59
B. Fertility levels:				
F_1 : Control	7.05	51.90	40.12	23.87
F_2 : Phosphorus @ 20 kg ha^{-1}	8.17	54.36	41.89	25.26
F_3 : Phosphorus @ 30 kg ha^{-1}	8.90	55.67	43.56	26.98
F_4 : Phosphorus @ 40 kg ha^{-1}	9.16	59.36	45.09	28.79
SE (d)	0.15	0.59	0.31	0.59
CD (P=0.05)	0.41	1.12	0.70	1.47

Table 2. Effect of different levels of AM fungi and phosphorus on economics under different treatments

Treatments	Cost of cultivation (INR ha^{-1})	Gross return (INR ha^{-1})	Net return (INR ha^{-1})	B:C Ratio
A. Inoculation level:				
I_1 : Control	26831.16	40447.8	13616.80	1.50
I_2 : AM fungi @ 8 kg ha^{-1}	27231.16	42577.0	15445.84	1.56
I_3 : AM fungi @ 12 kg ha^{-1}	27431.16	45099.6	17668.44	1.64
I_4 : AM fungi @ 16 kg ha^{-1}	27631.16	45774.2	18143.04	1.66
B. Fertility levels:				
F_1 : Control	26831.16	40106.8	13275.64	1.48
F_2 : Phosphorus @ 20 kg ha^{-1}	27974.63	42228.4	14253.77	1.51
F_3 : Phosphorus @ 30 kg ha^{-1}	28396.37	44705.2	16308.83	1.57
F_4 : Phosphorus @ 40 kg ha^{-1}	29118.10	47347.6	18229.50	1.63

grain ear^{-1} and test weight (Tables 1). Higher yield of barley under AM fungi and phosphorous fertility levels have already been reported by Abhijit et al. [16] and [17,20,21].

3.3 Economics

The highest total cost of cultivation was recorded in the inoculation level of AM fungi @ 16 kg ha^{-1} (INR 27631.16 ha^{-1}), AM fungi @ 12 kg ha^{-1} (INR 27231.16 ha^{-1}), and lowest in control (INR 26831.16 ha^{-1}). The highest gross return (INR 45774.2 ha^{-1}), net return (INR 18143.04 ha^{-1}) and benefit ratio (1.66) were observed with inoculation level of AM fungi @ 16 kg ha^{-1} followed by AM fungi @ 12 kg ha^{-1} while the lowest under control. The various fertility levels caused market variation in respect of cost of cultivation, gross return, net return and benefit: cost ratio. among Phosphorous fertility level, Phosphorus @ 40 kg ha^{-1} recorded the highest cost of cultivation (INR 29118.10 ha^{-1}), gross return (INR 47347.6 ha^{-1}), net return (INR 18229.50 ha^{-1}) and B:C ratio(1.63) followed by Phosphorus @ 30 kg ha^{-1}, Phosphorus @ 30 kg ha^{-1} and lowest under control. The source of income are only grain and straw produce, these are responsible for gross income under different treatment. These results confirm with the findings of [22,14,16].

4. CONCLUSION

On the basis of results obtained during the course of the investigations, the AM fungi @ 16 kg ha^{-1} inoculation level proved to be the most promising in yield attributes, yield, gross return, net return and benefit cost ratio (B:C ratio), compared to AM fungi @ 12 kgha^{-1}, AM fungi @ 8 kg ha^{-1} and control practices under rainfed condition. However, Phosphorus fertility level @ 40 kg ha^{-1} gave better yield attributes, yield and economics compared to Phosphorus @ 30 kg ha^{-1}, Phosphorus @ 20 kg ha^{-1} and control. On the basis of observed results, farmers are advised to raise barley with inoculate of AM fungi inoculation level @ 16 kg ha^{-1} along with the application of Phosphorus @ 40 kg ha^{-1} for obtaining the best yield attributes, yield, economics and soil health.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. El-Hashash EF, El-Absy KM. Barley (*Hordeum vulgare* L.) breeding. In Advances in plant breeding strategies: Cereals. 2019;1-45.
2. Kaur P, Ghoshal G, Banerjee UC. Traditional bio-preservation in beverages: fermented beverages. In Preservatives and preservation approaches in beverages. Academic Press. 2019;69-113.
3. Igiehon NO, Babalola OO. Biofertilizers and sustainable agriculture: exploring arbuscular mycorrhizal fungi. Applied Microbiology and Biotechnology. 2017;101(12):4871-4881.
4. Mohammadi K, Khalesro S, Sohrabi Y, Heidari G. A review: beneficial effects of the mycorrhizal fungi for plant growth. J. Appl. Environ. Biol. Sci. 2011;1(9):310-319.
5. Hussey VL. Do oxalic acid exudates from mycorrhizal fungi influence the uptake of phosphorus by primary producers in the karst critical zone of south west China? Doctoral Dissertation University of Bristol; 2019.

6. Borde M, Dudhane M, Kulkarni M. Role of arbuscular mycorrhizal fungi (AMF) in salinity tolerance and growth response in plants under salt stress conditions. In Mycorrhiza-eco-Physiology Secondary Metabolites Nanomaterials. 2017;71-86.
7. Boutasknit A, Baslam M, Ait-El-Mokhtar M, Anli M, Ben-Laouane R, Douira A, Meddich A. *Arbuscular mycorrhizal* fungi mediate drought tolerance and recovery in two contrasting carob (*Ceratonia siliqua* L.) ecotypes by regulating stomatal water relations and (in) organic adjustments. Plants. 2020;9(1):80.
8. Karthika KS, Rashmi I, Parvathi MS. Biological functions uptake and transport of essential nutrients in relation to plant growth. In Plant Nutrients and Abiotic Stress Tolerance. 2018;1-49.
9. Pattanayak SK, Sureshkumar P, Tarafdar JC. New vista in phosphorus research. Journal of the Indian Society of Soil Science. 2009;57(4):536-545.
10. Hasan M, Uddin MK, Muda Mohamed MT, Kee Zuan AT. Nitrogen and phosphorus management for Bambara groundnut (*Vigna subterranea*) production-A review. Legume Research: An International Journal. 2018;41(4).
11. Rao DLN, Aparna K, Mohanty SR. Microbiology and bioch. of soil organic matter carbon sequestration and soil health. Indian Journal of Fertilisers. 2019;15(2):124-138.
12. Zhang QC, Shamsi IH, Xu DT, Wang GH, Lin XY, Jilani G, Chaudhry AN. Chemical fertilizer and organic manure inputs in soil exhibit a vice versa pattern of microbial community structure. Applied Soil Ecology. 2012;57:1-8.
13. Gomez KA, Gomez AA. Statistical procedure for agricultural research with emphasis on rice 2nd Ed. IRRI Los Banos Philippine; 1976.
14. Jat SL, Sumeriya HK, Mehta YK. Influence of integrated nutrient management on content and uptake of nutrients on sorghum (*Sorghum bicolor* (L.) Moench). Crop Research Hisar. 2003;26(3):390-394.
15. Begum N, Begum D, Chen H. Role of *Arbuscular mycorrhizal* fungi in plant growth regulation: implications in abiotic stress tolerance. Front. Plant Sci. 2019;19(4):34-39.
16. Abhijit S, Singh H, Devi M. Economic evaluation of integrated nutrient management in wheat under adequate and limited irrigation supplies. Indian J. Hill Farming. 2004;17(1/2):19-23.
17. Brown LK, George TS, Thompson JA, Wright G, Lyon Dupuy L, Hubbard SF, White PJ. What are the implications of variation in root hair length on tolerance to phosphorous deficiency in combination with water stress in barley (*Hordeum vulgare*)?. Journals@Ovid Full TextAnnals of Botany. 2012;10(2):319-328.
18. Gauri Shankar Verma LP, Room Singh. Effect in integrated nutrient management on yield and quality of Indian mustard (*Brassica juncea* L.) and properties of soil. The Indian Journal of Agricultural Sciences. 2004;72(9):551-552.
19. Sjoberg Johanna, Martensson Anna, Persson Paula. Are field populations of arbuscular mycorrhizal fungi able to suppress the transmission of seed-borne *Bipolaris sorokiniana* to aerial plant parts. Journals@Ovid Full Text European Journal of Plant Pathology. 2007;117(1): 45-55.
20. Adeyemi N, Sakariyawo O, Atayese M. Yield and yield attributes responses of soybean (*Glycine max* L. Merrill) to elevated CO2 and *Arbuscular mycorrhizal* fungi inoculation in the humid transitory rainforest. Notulae Scientia Biologicae. 2017;9(2):233-241.
21. Zhang S, Lehmann A, Zheng W, You Z, Rillig MC. *Arbuscular mycorrhizal* fungi increase grain yields: A meta-analysis. New Phytologist. 2019;222(1):543-555.
22. Kahiluoto Helena, Ketoja Elise, Vestberg Mauritz, Saarela. Promotion of AM utilization through reduced P fertilization 2. Field studies. Journals@Ovid Full TextPlant & Soil. 2001;231(1):65-79.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/95006