The Pharma Innovation Journal 2022; 11(12): 6367-6369

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(12): 6367-6369

www.thepharmajournal.com
Received: 16-09-2022
Accepted: 20-10-2022

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Filled and unfilled spikelets of malt barley (*Hordeum vulgare* L.) crop as influenced by different fertility levels and liquid biofertilizers

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Abstract
A field experiment was conducted during 2020-21 and 2021-22 on clay loam soil having low in available nitrogen (278.36 to 279.42 kg ha^{-1}), medium in available phosphorus (18.73 to 20.39 kg ha^{-1}) and high in available potassium status (328.40 to 332.72 kg ha^{-1}) with slightly alkaline in reaction at the Instructional Farm, Department of Agronomy, Rajasthan College of Agriculture, MPUAT, Udaipur during *rabi* season 2020-21 and 2021-22 with the objective to evaluate the response of malt barley to fertility levels and biofertilizers. The experiment was laid out in randomized block design (Factorial) with 15 treatment combinations comprised of three fertility levels *i.e.* application of 70 kg N+40 kg P_2O_5 +25 kg K_2O ha^{-1}, 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} with five liquid biofertilizers *i.e.* control, *Azotobacter*, PSB, KMB and *Azotobacter* + PSB + KMB. The result revealed that malt barley crop fertilized with 70 kg N+40 kg P_2O_5 +25 kg K_2O ha^{-1} recorded highest number of filled spikelets ear^{-1} (55.35) which was significantly higher over rest of fertility levels. Further the results showed that seed inoculation with liquid biofertilizers *Azotobacter* + PSB + KMB significantly improved filled spikelets ear^{-1} (55.21) of malt barley crop.

Keywords: Malt barley, protein, starch, biofertilizers and fertility levels

Introduction
Barley is generally grown on marginal and sub-marginal land because of its low inputs requirement. In India, barley is mainly grown in the northern plains and concentrated in the states of Utter Pradesh, Haryana and Rajasthan. In India, barley was cultivated on 610.5 thousand ha area with 1600 thousand t of production at an average productivity of 26 q ha^{-1}. In India, Rajasthan is the largest state having more than 52% in production and 46% area followed by Uttar Pradesh. In Rajasthan, barley was cultivated on 312.7 thousand ha area with 1059.3 thousand t of production at an average productivity of 33.88 q ha^{-1} (IIWBR, 2020-21) [4]. The use of two-rowed barley for malting and brewing industry has picked up recently with increased consumption of beer and other malt-based products in many countries (Gupta *et al.*, 2010) [3]. Presently about 20-25% of total barley production is used in the preparation of malt which is utilized for brewing, distillation, baby foods, confectionaries cocoa- malt drink and medicinal syrups. Adequate mineral fertilization is considered to be one of the most important prerequisite in this respect. Despite the application of recommended quantities of major nutrients, the increase in yield is not encouraging. Nitrogen is the most important nutrient for plant growth and development. It is an integral part of chlorophyll, which is essential for photosynthesis. Phosphorus nutrition plays key role in plant metabolism. Being involve in various biochemical processes, it ensures transfer and storage of energy as ADP and ATP, permits conversion and transmission of genetic characters as it is a constituent of DNA and RNA. Potassium plays an important role in the maintenance of cellular organism by regulating cell membrane and keeping the protoplasm in a proper degree of hydration. On the other hand, biofertilizers play a very significant role in improving soil fertility by fixing atmospheric nitrogen both in association with plant roots and without it, solubilize insoluble soil phosphates and produces plant growth substances in the soil and solubilize inorganic potassium from insoluble compounds and make it available for plant uptake. Therefore, keeping in view of above facts the present study has been undertaken.

Material And Methods
The field experiment was conducted during *rabi* 2020-21 and 2021-22 at the Instructional

Farm, Department of Agronomy, Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan, India. The soil of experimental site was clay loam in texture, slightly alkaline in reaction, low in available nitrogen, medium in available phosphorus and high in available potassium status. The experiment was laid out in randomized block design (Factorial) with 15 treatment combinations comprised of three fertility levels *i.e.* application of 70 kg N+40 kg P_2O_5 +25 kg K_2O ha^{-1}, 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} with five liquid biofertilizers *i.e.* control, *Azotobacter*, PSB, KMB and *Azotobacter* + PSB + KMB. The total quantity of phosphorus and potassium with half dose of nitrogen were drilled in furrows before sowing of seed. Remaining half dose of nitrogen was top dressed at the time of first irrigation. The seeds were treated with liquid biofertilizers using 5 ml kg^{-1} seed through standard procedure 2-3 hours before sowing as per treatment. The seeds were sown in furrow opened at the depth of about 4-5 cm using seed rate of 100 kg ha^{-1} keeping inter row spacing of 20 cm. From randomly selected five productive ears, the grain bearing spikelet were detached and counted to workout average number of filled spikelets
ear^{-1}. After separating filled spikelets from selected productive ears, the number of unfilled spikelets *i.e.*, which do not bear grain were counted and averaged.

Result and Discussion

Filled spikelet ear^{-1}

Fertility levels

Irrespective of years as well as in pooled analysis, increasing fertility levels had significant effect on filled spikelet ear^{-1} (Table 1). The malt barley crop fertilized with 70 kg N+40 kg P_2O_5 +25 kg K_2O ha^{-1} produced ears having highest number of filled spikelets as compared to 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.

Two years mean data show that application of 70 kg N+40 kg P_2O_5 +25 kg K_2O ha^{-1} significantly improved filled spikelet ear^{-1} by 7.8 and 18.29 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.

Liquid biofertilizers

It is evident from data that inoculation of malt barley seed with liquid biofertilizers alone and in combination significantly influenced filled spikelet ear^{-1} during both the years of investigation as well as in pooled analysis. The significant improvement in number of mean filled spikelet ear^{-1} were by 9.41, 7.20, 7.05 and 16.59 per cent due to single inoculation of *Azotobacter*, PSB, KMB and combined application of *Azotobacter* + PSB + KMB over control, respectively. Among liquid biofertilizers, the crop under the influence of conjoint inoculation with *Azotobacter* + PSB + KMB produced highest number of filled spikelet ear^{-1} which were significantly higher over inoculation of *Azotobacter*, PSB and KMB alone during both years. On pooled basis, co inoculation of *Azotobacter* + PSB + KMB significantly increased filled spikelet ear^{-1} by 6.56, 8.76 and 8.91 per cent over single inoculation of *Azotobacter*, PSB and KMB, respectively.

Unfilled spikelet ear^{-1}

Fertility levels

A reference to data (Table 1) indicates that fertility levels caused significant influence on number of unfilled spikelet ear^{-1} of malt barley crop during both the years of experimentation as well as in pooled analysis. Among fertility levels, least number of unfilled spikelet ear^{-1} were observed under application of 70 kg N+40 kg P_2O_5 +25 kg K_2O ha^{-1} which recorded significant reduction 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, the significant reduction in number of unfilled spikelet ear^{-1} due to application of 70 kg N+40 kg P_2O_5 +25 kg K_2O ha^{-1} were 12.41 and 21.15 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.

Liquid biofertilizers

Irrespective of the years as well as in pooled analysis, inoculation of malt barley seed with liquid biofertilizers alone and in combination significantly influenced number of unfilled spikelet ear^{-1}. The mean data show that inoculation of *Azotobacter*, PSB, KMB alone and in combination of *Azotobacter* + PSB + KMB significantly reduced number of unfilled spikelet ear^{-1} to the extent of 9.94, 7.35, 6.36 and 29.82 per cent over control, respectively. Among liquid biofertilizers, co inoculation with *Azotobacter* + PSB + KMB produced least number of unfilled spikelet ear^{-1} which were significantly reduced over inoculation with *Azotobacter*, PSB and KMB alone during both years. On pooled basis, the significant reduction in number of unfilled spikelet ear^{-1} due to co inoculation with *Azotobacter* + PSB + KMB was 22.07, 24.24 and 25.05 per cent over single inoculation of *Azotobacter*, PSB and KMB, respectively.

The results indicated that filled spikelets ear^{-1} was maximized when crop was fertilized with 70 kg N+40 kg P_2O_5 +25 kg K_2O ha^{-1} (Table 1). It has been well emphasized that application of adequate fertilization to malt barley significantly improved overall growth of crop in term of dry matter accumulation m^{-1} row by virtue of its impact on morphological and photosynthetic component of growth along with accumulation of nutrients. This suggests greater availability of nutrients and metabolites for growth and development of each reproductive structure which ultimately led to realization of their genetic potential up to highest level. A faster growth rate in terms of dry matter production as evince from higher CGR and RGR under the influence of adequate fertilization might have played a significant role in reducing competition for photosynthates and nutrients with mother shoots as well as between tillers resulting in their greater survival till harvest. On the other hand, adequate supply of photosynthates due to higher photosynthetic efficiency at ear emergence might have enhanced number of flowers and their fertilization resulting in higher number of filled spikelet and grains ear^{-1}. The results of present investigation indicating positive response of various yield components to fertility levels corroborates finding of several researchers (Shantveerayya *et al.*, 2017; Choudhary *et al*., 2018; Dahiya *et al.*, 2019) [8, 1, 2].

Conjoint inoculation with liquid biofertilizer *Azotobacter* + PSB + KMB significantly enhanced filled spikelet ear^{-1}. The inoculation of seed with nitrogen fixer increased the concentration of nitrogen in the rhizosphere and they fixed atmospheric and organic nitrogen in becteriodes and later on oxidized to nitrate form. Chelating effect of PSB reduces the phosphorus fixation and solubilized the fixed form of

phosphorus leading to more uptake of phosphorus. Potassium mobilizing bacteria mobilizes potassium which has strong mobility in plants and plays an important role in regulating cell osmotic pressure and balancing the cations and anions in the cytoplasm. It also involved in regulation of stomatal opening and closing, cell elongation and other physiological process. Uptake of micronutrient and secondary nutrients enhanced due to greater expansion of roots under increased availability of nitrogen, phosphorus and potassium might have enhanced photosynthates and their partitioning among vegetative and reproductive plant parts which ultimately improve the number of spikeletes ear^{-1}. (Saber *et al.,* 2012; Kumawat *et al.,* 2016; Neelam *et al.,* 2018) [7, 5, 6].

Table 1: Effect of fertility levels and biofertilizers on yield attributes of malt barley

Treatments	Filled spikelet ear^{-1}			Unfilled spikelet ear^{-1}		
	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}	45.66	47.92	46.79	5.36	4.66	5.01
60 kg N+30 kg P_2O_5+20 kg K_2O ha^{-1}	50.20	52.50	51.35	4.86	4.16	4.51
70 kg N+40 kg P_2O_5+25 kg K_2O ha^{-1}	54.21	56.50	55.35	4.31	3.60	3.95
S.Em.+	0.91	0.87	0.63	0.08	0.07	0.05
C.D. (P=0.05)	2.59	2.48	1.77	0.22	0.20	0.15
Liquid biofertilizers						
Control	46.20	48.50	47.35	5.37	4.68	5.03
Azotobacter	50.62	53.00	51.81	4.89	4.17	4.53
PSB	49.67	51.85	50.76	5.01	4.32	4.66
KMB	49.61	51.77	50.69	5.06	4.37	4.71
Azotobacter + PSB + KMB	54.01	56.41	55.21	3.89	3.17	3.53
S.Em.+	1.17	1.12	0.81	0.10	0.09	0.07
C.D. (P=0.05)	3.34	3.20	2.28	0.29	0.26	0.19

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 enhancing number of spikelets ear^{-1} malt barley crop.

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