Response of Biofertilizer and Molybdenum on Growth and Yield of Barley (*Hordeum vulgare* L.)

Abstract

The field experiment entitled "Impact of Biofertilizer and Molybdenum on Growth and Yield of Barley (*Hordeum vulgare* L.)" was conducted during *rabi*, 2023-24 at research farm, Vivekananda Global University, Jaipur. The experiment was layout in Randomized Block Design (RBD). The treatment consisted of biofertilizers like *Azotobacter* and PSB and three level of Molybdenum (400, 600 and 800 ppm) and control. The soil in the experimental area was sandy loam with pH (7.81), Organic Carbon (0.21%), Available N (132.5 kg/ha), Available P (21.13 kg/ha) and Available K (203.24 kg/ha). Seed rate is 100 kg/ha. The application of biofertilizers + PSB + 800 ppm Mo significantly increased the Plant height (110.46cm), Dry matter accumulation (542.54g/m^2), No. of tillers/ running row meter (93.51), Number of effective tillers m^{-2} (199.86), Number of grains $spike^{-1}$ (53.60), Grain yield (3450 kg/ha) and Straw Yield (6562 kg/ha) of barley over the control.

Introduction

Barley (*Hordeum vulgare* L.) is an important *Rabi* cereal crop in northern plains of India comprising the states of Uttar Pradesh, Haryana, Rajasthan, Punjab, Madhya Pradesh and Uttranchal. Barley is grown for many purposes, but mainly used for animal feed, human consumption, or malting. It can be rolled, crushed, flaked, or pelleted, but byproducts from malting and brewing are also utilised in feed manufacturing.Hulless barley is often referred as "naked barley" and barley requires minimum cleaning compared to hulled barley. Each 100 g of barley grain contain 10.6 g protein, 2.1 g fat, 64.0 g carbohydrate, 50.0 mg calcium, 6.0 mg iron, 31.0 mg vitamin B_1, 0.1 mg vitamin $B_2$and 50.0 µg folate (Vaughan *et al.,* 2006).

There are numerous varieties of biofertilizers such *Rhizobium, Azotobacter, Azospirillum*, Blue green algae and Azolla. Biofertilizers add nutrients through the natural processes of N_2 fixation, solubilizing phosphorus and stimulating plant growth through the synthesis of growth-promoting substances. In addition to helping plant development, biofertilizers lower the price of chemical fertilisers like potassium, phosphorous and nitrogen. The soil's organic matter is increased and the nutrient cycle is restored by the microorganisms in biofertilizer. Application of bio-fertilizers seems to be a good alternative to get yield of high quality and reduce environmental pollution (Shevananda, 2008).

Molybdenum directly affects the uptake and fixing of nitrogen in pulse crops because it is an enzyme component of nitrate reductase and nitrogenase enzymes. The vitamin works better and acts faster when sprayed foliarly rather than being applied topically. Additionally, molybdenum is essential for the structural integrity of cell walls and membranes, protein synthesis, and nitrogen fixation (Hansch and Mendel, 2009). It is an essential component of the enzyme nitrate reductase, which catalyses the conversion of NO_3^- to NO_2^-.It's plays an important role in symbiotic nitrogen fixation. Without sufficient amounts of this element, nitrogen fixation cannot take place. Nitrogenase, the enzyme that fixes nitrogen, is a compound of molybdenum. Legumes grew and yielded much more when the package and methods were applied simultaneously and the maximum yield was achieved when lime seed coating was applied in conjunction with the prescribed dosages of *rhizobium* and ammonium molybdate (Padhi *et al*., 2018).

Material and method

A field experiment entitled "Response of Biofertilizer and Molybdenum on Growth and Yield of Barley (*Hordeum vulgare* L.)" was conducted at research farm, Vivekananda Global University, Jaipur during *rabi* seasons of the years 2023-24. The details of experimental techniques, materials used and criteria adopted for evaluation of treatments during the course of present investigation are described in this chapter. The experiment was laid out at Agronomy Farm, Vivekananda Global University, Jaipur during rabi seasons of 2023-24. Jaipur is situated at 260 5" North latitude and 750 28" East longitudes at an altitude of 427 meters above mean sea level. In Rajasthan, this region falls under Agro-climatic zone-IIIA (Semi-Arid Eastern Plains).The climate of this region is typically semi-arid, characterized by extremes of temperature during both summer and winter. The average annual rainfall of this tract varies from 300 mm to 400 mm and is mostly received during the months of July to September. All agronomic practices are followed in order in the crop period. Experimental data collected was subjected to statistical analysis by adopting Fisher's method of analysis of variance (ANOVA) as outlined by Gomez and Gomez (1984). Critical Difference (CD) values were calculated wherever the 'F' test was found significant at 5 percent level.

Table 1 Treatment combination

S. No.	Treatments	Symbols
1.	Control (RDF 60: 30: 20 kg/ha NPK)	T1
2.	*Azotobacter* + 400 ppm Mo	T2
3.	*Azotobacter* + 600 ppm Mo	T3
4.	*Azotobacter* + 800 ppm Mo	T4
5.	PSB + 400 ppm Mo	T5
6.	PSB + 600 ppm Mo	T6
7.	PSB + 800 ppm Mo	T7
8.	*Azotobacter* + PSB + 400 ppm Mo	T8
9.	*Azotobacter* + PSB + 600 ppm Mo	T9
10.	*Azotobacter* + PSB + 800 ppm Mo	T10

Result and Discussion

Growth attributes

Plant height

At 120 DAS, significantly and higher plant height (110.46cm) was recorded in treatment 10 [*Azotobacter* + PSB + Mo 800 ppm] as compare to the rest of the treatment. However, the treatment-9 [PSB + Mo 800 ppm] (105.68cm) was found to be statistically at par with treatment-10 [*Azotobacter* + PSB + Mo 800 ppm].Increase in the availability or supply of plant nutrients, biofertilizers promote better development. As the nitrogen fixer inoculated seed fixed atmospheric and organic nitrogen in becteriodes and subsequently oxidised to nitrate form, the quantity of nitrogen in the rhizosphere rose. Azotobacter may enhance plant growth and root development by excreting vitamins, auxins, and amino acids (Mohanta *et al.*, 2020), Chand *et al.* (2014) claimed that PSB created organic acids such as fumaric, citric, glyoxalic, malic and succinic acid. This may have boosted the mineralization of phosphorus from insoluble organic matter to soluble phosphorus, increasing the amount of phosphorus available in soil. The longer lifespan appears to be caused by the biofertilizers improved ability to improve the nutritional condition of the plant (straw and grain) and their ability to produce enough metabolites. It might be because biofertilizers produce growth hormones, which causes increased vegetative growth and delays the phenological stages of crop growth. The results of investigation corroborated findings of Kumar (2005) and Shirinzadeh*et al*. (2013).

Dry matter accumulation

Biofertilizer and molybdenum significantly enhanced the dry matter accumulation of barley over control. Application of T_{10} (*Azotobacter* + PSB + Mo 800 ppm recorded the maximum dry matter accumulation 541.54 g at 120 DAS. Further, the application of T_{10} treatment recorded significantly maximum dry matter accumulation as compared to control (T_1) at 60, 90 and 120 DAS.Increase in the availability or supply of plant nutrients, biofertilizers promote better development. The fact that molybdenum is a component of the enzyme nitrogenase, which is necessary for the process of symbiotic nitrogen fixation, may also have contributed to the no. Table improvement in these features. Additionally, it is a component of nitrate reductase, which lowers nitrates to ammonia before amino acid and protein synthesis occurs in plant cells. This process promotes improved plant height and dry matter output. Certain enzymes also use molybdenum to perform redox reactions. The following enzymes need molybdenum to function: sulfite oxidase, nitrate reductase, xanthine dehydrogenase, and aldehyde oxidase. The increased molybdenum application might have increased metabolic processes in plants resulting in greater meristematic activity and apical growth, thereby increasing plant height and also formation of higher number of leaves per plant, ultimately resulting in improved photosynthetic surface area of the plant. These results corroborate the findings of Bandyopadhyay and Basu (2003), Valenciano *et al.*, (2011), Gad and Kandil (2013), Khan *et al.*, (2014) and Yadav *et al*. (2017).

Number of tillers/running row meter

Biofertilizer and molybdenum significantly enhanced the number of tillers/ running row meter of barley over control. Application of T_{10} (*Azotobacter* + PSB + Mo 800 ppm) recorded the maximum no. of tillers/ running row meter 93.51at 120 DAS. Further, the application of T_9 (PSB + Mo 800 ppm) treatment recorded significantly maximum no. of tillers/ running row meter (92.21) as compared to control (T_{10}) at 120 DAS.

Yield attributes and yield

Number of effective tillers/m^2

The minimum number of effective tillers/m^2 161.57 per metre row length was recorded under the control (T_1) treatment, and the highest number of effective tillers 199.86 per meterwas recorded in treatment T_{10} (*Azotobacter* + PSB + Mo 800 ppm).

The improvement in dry matter production combined with its efficiency (CGR) and sink components clearly demonstrate the good impact of liquid biofertilizers on preserving the source-sink relationship, which may account for the notable increase in grain yield seen after inoculation. The significant increase in grain yield following biofertilizer inoculation was due to their significant influence on both the source and sink components of the crop, as evidenced by the positive correlation between grain yield and CGR across different crop durations and yield components. The beneficial effect of liquid biofertilizers on barley productivity was also reported by several researchers (Saber *et al.*, 2012; Kumawat *et al.*, 2016; Neelam *et al.*, 2018). Mo has unique role in enhancing nitrogen fixation thereby increasing its availability to the plants for efficient growth and development of plants in terms of photosynthetic area which 57 enhanced the photosynthesis and synthesis of other metabolites for plant use. The increase in yield and yield characters could be attributed to increased size of source and consequently enhanced translocation of photosynthates towards newly formed sinks (pods and seeds). The results on seed and straw yields thus confirmed the trend observed in growth and yield attributing characters with application of molybdenum, Luthra and Kothari (2000), Vyas *et al*. (2003), Kumar and Sharma (2005), Valenciano *et al.* (2011), Gad (2012), Khan *et al*. (2014), Manohar (2014) and Yadav *et al.*, (2017) also observed significant improvement in yield attributes and yield of different crops due to application of molybdenum.

Number of grains/spike

The highest number of grains spike^{-1} (53.60) recorded in treatment T_{10} (*Azotobacter* + PSB + Mo 800 ppm over all various treatments and the control recorded significantly lowest number of grains spike^{-1} (44.88) overall various treatments.

Test weight (g)

The maximum test weight (43.59 g) was recorded with the application of T_{10} (*Azotobacter* + PSB + Mo 800 ppm) this treatment at par with T_9 (PSB + Mo 800 ppm), T_8 (*Azotobacter* + Mo 800 ppm). The minimum test (37.90 g) was recorded in control (T_1).

Grain yield (kg ha^{-1}), Straw yield (kg ha^{-1}) and Harvest index (%)

The application of T_{10}*Azotobacter* + PSB + Mo 800 ppm recorded the significantly higher grain yield (3450 kg ha^{-1}) which was statistically remained at par with the application of T_7*Azotobacter* + PSB + Mo 600 ppm (3363 kg ha^{-1}) and the lowest grain yield (2750 kg ha^{-1}) recorded in control (T_1). In case of Strawyield application of T_{10} *Azotobacter* + PSB + Mo 800 ppm also recorded the significantly higher Strawyield (6562 kg ha^{-1}) which was statistically remained at par with the application of T_9 PSB + Mo 800 ppm (6232 kg ha^{-1}) and the lowest straw yield (3425 kg ha^{-1}) recorded in control (T_1). The application of control (T_1) recorded highest harvest index (44.53%) and minimum harvest index (39.84%) was recorded in PSB + Mo 600 ppm (T_6).The improvement in dry matter production combined with its efficiency (CGR) and sink components clearly demonstrate the good impact of liquid biofertilizers on preserving the source-sink relationship, which may account for the notable increase in grain yield seen after inoculation. The significant increase in grain yield following biofertilizer inoculation was due to their significant influence on both the source and sink components of the crop, as evidenced by the positive correlation between grain yield and CGR across different crop durations and yield components. The beneficial effect of liquid biofertilizers on barley productivity was also reported by several researchers (Saber *et al.*, 2012; Kumawat *et al.*, 2016; Neelam *et al.*, 2018). Mo has unique role in enhancing nitrogen fixation thereby increasing its availability to the plants for efficient growth and development of plants in terms of photosynthetic area which 57 enhanced the photosynthesis and synthesis of other metabolites for plant use. The increase in yield and yield characters could be attributed to increased size of source and consequently enhanced translocation of photosynthates towards newly formed sinks (pods and seeds). The results on seed and straw yields thus confirmed the trend observed in growth and yield attributing characters with application of molybdenum, Luthra and Kothari (2000), Vyas *et al.* (2003), Kumar and Sharma (2005), Valenciano *et al.* (2011), Gad (2012), Khan *et al.* (2014), Manohar (2014) and Yadav *et al.*, (2017) also observed significant improvement in yield attributes and yield of different crops due to application of molybdenum.

Table2Response of Biofertilizer and Molybdenum on plant height, dry matter,accumulation (g/m^2) and No. of tillers/running rowmeter on barley.

Treatment	Treatment combination	Plant height (cm)	Dry matter accumulation (g/m^2)	No. of tillers/ running row meter
		120 DAS	120 DAS	120 DAS
T1	Control	94.39	430.75	79.85
T2	*Azotobacter* + Mo 400 ppm	96.33	449.01	80.85
T3	PSB + Mo 400 ppm	98.73	443.83	81.74
T4	*Azotobacter* + PSB + Mo 400 ppm	98.51	464.95	82.56
T5	*Azotobacter* + Mo 600 ppm	100.07	460.09	83.51
T6	PSB + Mo 600 ppm	102.97	502.71	84.51
T7	*Azotobacter* + PSB + Mo 600 ppm	101.71	528.54	85.61
T8	*Azotobacter* + Mo 800 ppm	102.27	538.65	86.54
T9	PSB + Mo 800 ppm	105.68	538.76	92.21
T10	*Azotobacter* + PSB + Mo 800 ppm	110.46	542.54	93.51
	SEm±	2.90	14.01	2.51
	CD (P=0.05)	8.62	41.61	7.47
	CV (%)	5.0	5.0	5.1

Fig 1 Response of Biofertilizer and Molybdenum on plant height, dry matter,accumulation (g/m²) and No. of tillers/running rowmeter on barley.

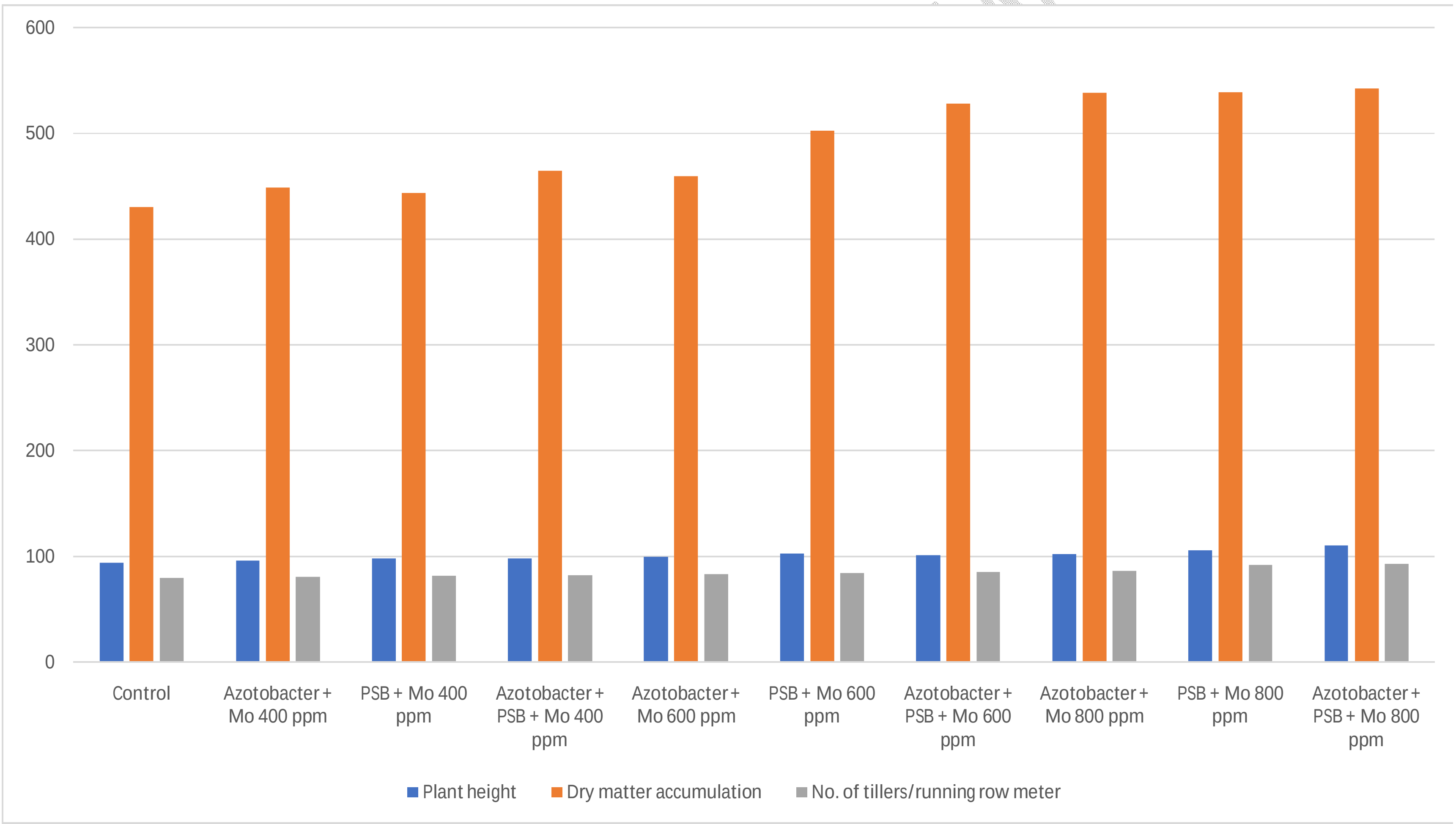


Table3Response of Biofertilizer and MolybdenumonNo. of effective tillers m^{-2},No.of grains $spike^{-1}$ and test weight (g) of barley

Treatment	Treatment combination	No. of effective tillers m^{-2}	No. of grains $Spike^{-1}$	Test weight (g)
T1	Control	161.57	44.88	37.90
T2	*Azotobacter* + Mo 400 ppm	166.57	45.68	38.87
T3	PSB + Mo 400 ppm	170.54	46.81	38.81
T4	*Azotobacter* + PSB + Mo 400 ppm	174.87	47.91	39.67
T5	*Azotobacter* + Mo 600 ppm	182.83	48.80	39.73
T6	PSB + Mo 600 ppm	185.85	49.79	40.91
T7	*Azotobacter* + PSB + Mo 600 ppm	189.17	51.10	40.52
T8	*Azotobacter* + Mo 800 ppm	190.79	52.16	41.92
T9	PSB + Mo 800 ppm	193.67	53.06	43.09
T10	*Azotobacter* + PSB + Mo 800 ppm	199.86	53.60	43.59
	SEm±	5.28	1.64	1.16
	CD (P=0.05)	15.70	4.86	3.44
	CV (%)	5.0	5.7	5.0

Fig 2Response of Biofertilizer and MolybdenumonNo. of effective tillers m^{-2},No.of grains spike^{-1} and test weight (g) of barley

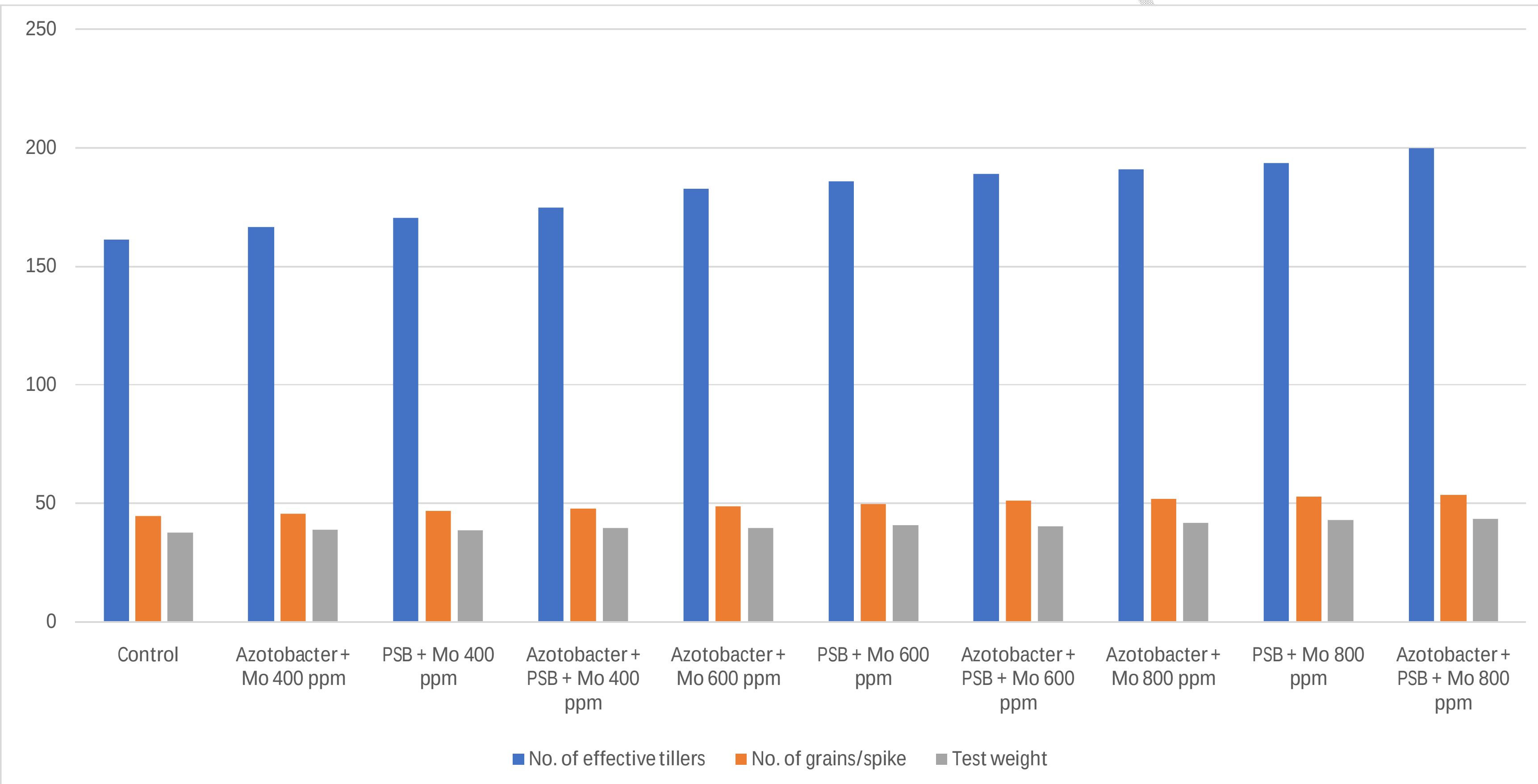
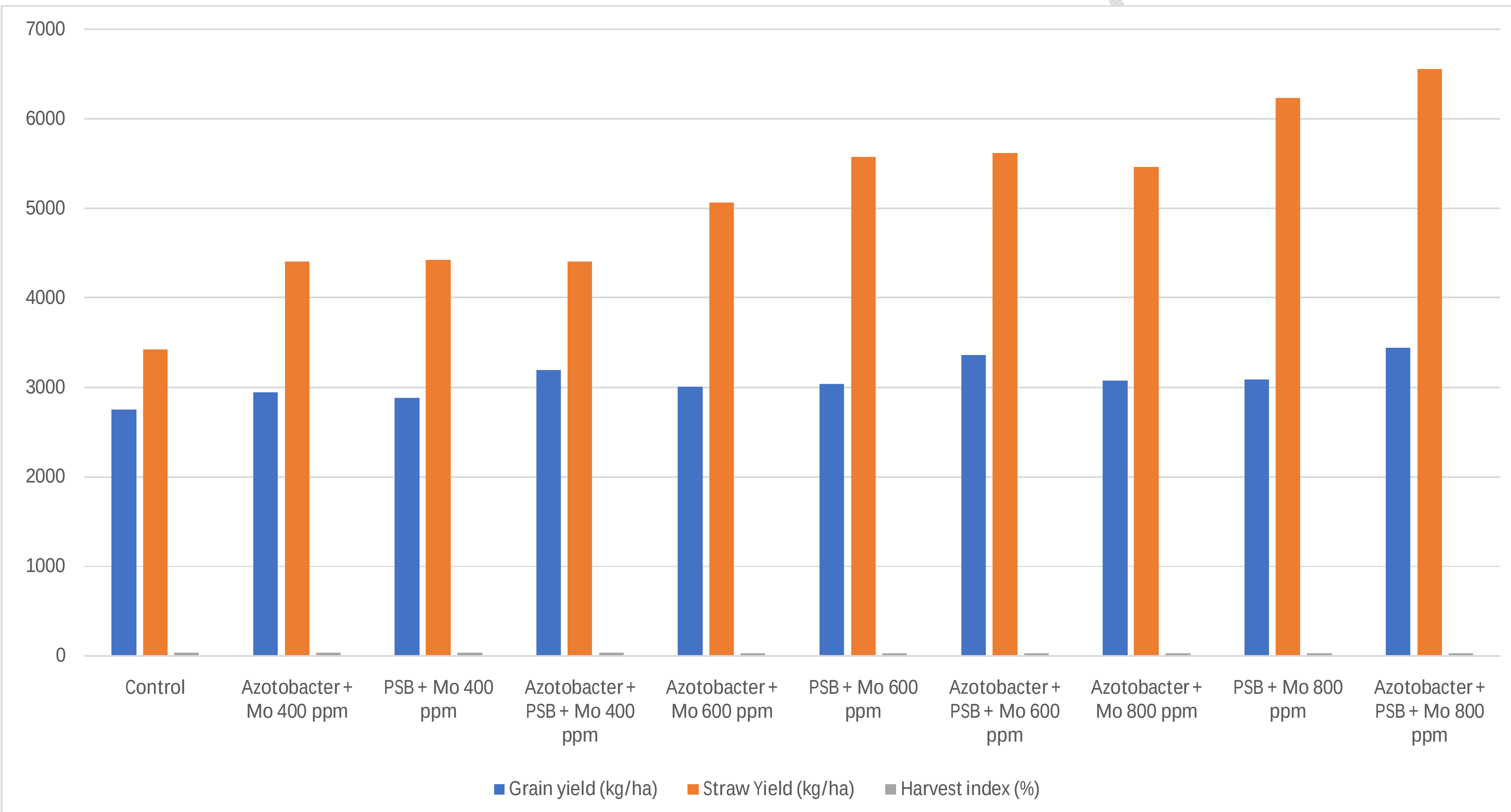


Table4Effect of different level of biofertilizer and nitrogen on grain yield (q ha^{-1}), Stover yield (q ha^{-1}) and harvest index (%) of barley

Treatment	Treatment combination	Grain yield (q ha^{-1})	Stover yield (q ha^{-1})	Harvest Index (%)
T1	Control	2750	3425	38.32
T2	*Azotobacter* + Mo 400 ppm	2951	4413	40.08
T3	PSB + Mo 400 ppm	2884	4428	39.44
T4	*Azotobacter* + PSB + Mo 400 ppm	3199	4413	42.02
T5	*Azotobacter* + Mo 600 ppm	3008	5068	37.25
T6	PSB + Mo 600 ppm	3039	5578	35.27
T7	*Azotobacter* + PSB + Mo 600 ppm	3363	5622	37.43
T8	*Azotobacter* + Mo 800 ppm	3080	5461	36.07
T9	PSB + Mo 800 ppm	3089	6232	33.14
T10	*Azotobacter* + PSB + Mo 800 ppm	3450	6562	34.46
	SEm±	143.02	341.56	1.44
	CD (P=0.05)	433.92	1053.23	4.62
	CV (%)	6.9	10.9	6.3

Fig 3Response of Biofertilizer and Molybdenumongrain yield (q ha^{-1}), Stover yield (q ha^{-1}) and harvest index (%) of barley



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