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Ratan Singh
School of Agriculture, ITM University, Gwalior, Madhya Pradesh, India

M Devender Reddy
M.S. Swaminathan School of Agriculture, Centurion University of Technology and Management, Paralakhemundi, Odisha, India

Girish Pandey
School of Agriculture, ITM University, Gwalior, Madhya Pradesh, India

Anuj Kumar
School of Agriculture, ITM University, Gwalior, Madhya Pradesh, India

Corresponding Author:
Ratan Singh
School of Agriculture, ITM University, Gwalior, Madhya Pradesh, India

Effect of different levels of phosphorus on performance of barley (*Hordeum vulgare* L.)

Ratan Singh, M Devender Reddy, Girish Pandey and Anuj Kumar

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Abstract
An experiment on response of barley varieties (Super laxmi, NDB-2 and NDB-1445) to levels of phosphorus (0, 15, 30 and 45 kg ha^{-1}) was conducted during 2015-16 rabi season at ITM University, Gwalior. Variety Super laxmi recorded significantly higher plant height, number of tillers, dry matter production, spike length, 1000 grain weight and grain and straw yield over varieties NDB-2 and NDB-1445. Application of phosphorus at 30 and 45 kg ha^{-1} resulted in significantly higher plant hight, tiller number, dry matter production, spike length, 1000 grain weight, grain, straw and biological yield over that of 0 and 15 kg phosphorus ha^{-1}. The harvest index was higher at 0 level of phosphorus over that recorded with phosphorus application and similar among other phosphorus levels.

Keywords: Barley, grain yield, phosphorus levels, varieties

Introduction
Barley (*Hordeum vulgare* L.) is one of the most important cereal crop of the world. In India, it is grown in *Rabi* season and occupies area of 0.65 million hectares with the production of 1.60 million tonnes with a productivity of 2.46 t ha-1 (www. Farmerfriend.info>Barley). The average yield of barley in India is low as compared to the average yield of this crop in other countries. In India, the cultivation of barley is being done on the large scale in U.P., Rajasthan, Bihar, M.P., Punjab, Haryana and Himachal Pradesh.
In areas of low temperature, mainly for the hills some high yielding hull less barley varieties have been developed but their performance in comparison to hulled ones, under sound agronomic management in the plains have not been explored so far especially in Gwalior region. Hence, there is a need for assessing the suitability of popular varieties for Gwalior region of M.P.
Phosphorus is key element for increasing yield of field crops. The main problem associated with the use of phosphorus fertilizers is their low availability primarily due to immobilization and fixation in soil and therefore, the crops utilize only 10-25 per cent of applied phosphorus. The availability of phosphorus in soil is very critical as a portion of soil phosphorus is found in inorganic form such as phytin, phospholipids and nucleoproteins, which can be available to plant only after its mineralization by soil micro organisms.
Phosphorus deficiency is almost of universal occurrence in Indian soils. Heavy crop removal under intensive cultivation and non addition of organic matter to the soil are the principal factor responsible for phosphorus deficiencies. In Barley, various studies showed that increasing levels of phosphorus increases the growth and grain yield (Agrawal and De, 1979), the number of fertile tillers per plant, number of grains per ear and grain and straw yield (Choudhary *et al.*, 1971; Singh and Prasad, 1972; and Warsi *et al.*, 1976) [2, 10, 11].
Keeping the above points in view, an investigation was conducted to assess the phosphorus requirement for barley (*Hordeum vulgare* L.) for Gwalior (M.P.) region.

Material and Methods
An experiment was conducted at ITM University Gwalior on effect of different levels of phosphorus on performance of barley (*Hordium vulgare* L.) during rabi season of 2015-16 at ITM university, Gwalior, Madhya Pradesh. Three food barley varieties (NDB-2, Super Laxmi, and NDB-1445) and four different levels of Phosphorus (0, 15, 30 and 45 kg ha^{-1}) were tried in split plot design with varieties in main plots and Phosphorus levels in sub plots and three treatments were replicated three times.

During the crop growth period the maximum temperature varied between 18.9 ºC in January third week to 40.1 ºC April first week and minimum temperature ranged from 3.9 ºC in third week to 23 ºC in April second week.

The experiment site falls under humid sub-tropical climate and located in between 23^0 10' N latitude and 79^0 54' E longitudes at an elevation of 411.98 meters above mean sea level. The soil type of experimental field was sandy loam in nature with pH of 7.4 and EC 0.29 dsm-1, having 242 kg available nitrogen, 20.5 kg available phosphorus, 456 kg available potassium, 8.1 kg available sulphur per hectare.

Three varieties (Super laxmi, NDB 2 and NDB 1445) of barley were sown in well prepared field on Nov 5, 2015 manually at 20 cm row to row distance and 10 cm between plants at the rate of 100 kg seed ha^{-1} and harvested on April 24, 2016.

The nitrogen was applied at 80 kg ha^{-1} and potassium at 30 kg K_2 O ha^{-1}. Cow dung at 10 t ha^{-1} and 50% N and entire level of K along with P levels were applied at sowing. Remaining 50% N was applied in two equal splits at 30 and 50 days after sowing.

Two manual weedings were done, first after 1st irrigation (30 Dyas after sowing, DAS) and second at 45 DAS. To protect the crop from insects Rogor (0.05%) was sprayed once. A light irrigation was given immediately after sowing and two irrigations were givens during crop period.

All the agronomic management practices were done uniformly in all the treatments. Two irrigations were given during the entire period of crop, besides pre sowing irrigation.

The data on plant height was recorded on five plants which were tagged randomly in each treatment and in each replication. The observations on numbers of tiller per meter row length and yield attributes number of effective tiller per meter row length, ear head length (cm), number of grains per ear head, 1000 grain weight, biological, grain and straw yield were recorded. The grain and straw yields were recorded as per standard procedure.

The data obtained on various observations were subjected to statistical analysis by using the techniques of the analysis of variance (ANOVA) and the treatment was tested by F test and Critical difference (CD) at 5% level of significance (Panse and Sukhatme, 1989) for each character to compare the differences among treatment means.

Harvest Index, the ratio of economic yield to the biological yield. In case of cereals, it is the ratio of grains to the total dry matter and expressed in per cent age as fallows.

$$\text{Harvest Index (\%)} \frac{\text{Economic yield (grain yield)}}{\text{Biological yield (grain + straw)}} \text{X } 100$$

Results and Discussion

Varieties

Growth

The number of plants m^{-2} at 10 days after sowing did not differ among varieties indicating that the plant population among varieties was uniform. At harvest, the plant height of Super laxmi was significantly higher than that of NDB-2 and NDB -1445. The plant height in latter two varieties was comparable with each other. On the other hand, the tiller number and dry matter observed at harvest in Super laxmi was significantly higher than that of NDB -1445 and comparable with that of NDB -2. The tiller number and dry matter at this stage in NDB -2 and NDB -1445 was at par with each other.

Yield and Yield attributes

The spike length, number of grains, spike lets per spike and 1000 grain weight observed in Super laxmi and NDB -2 were comparable with each other and significantly Superior over that of NDB -1445.

The variety Super laxmi produced significantly higher grain yield over NDB -2 which recorded significantly more yield than variety NDB -1445. The straw yield recorded with variety Super laxmi was significantly greater than that of NDB -2 and NDB -1445. The straw yield of latter two varieties was comparable with each other. The varieties Super laxmi recorded significantly higher biological yield with that of NDB -2 and NDB1445. The biological yield observed in latter two varieties was comparable with each other. The harvest index was more in NDB -2 followed by NDB -1445 and Super laxmi.

The growth parameters like plant height, number of tillers and effective tillers, dry matter at harvest and yield attributes like Spike length, 1000 grain weight were significantly greater in Super luxmi over other two varieties. The greater values of growth and yield attributes in Super laxmi variety has resulted significant increase in grain yield over NDB-2 and NDB -1445. Further, these characters had positive correlation with grain yield indicating that any increase in yield attributes and growth result in increased grain yield (Table 4).

Phosphorus levels

Growth

The number of plants m^{-2} at 10 days after sowing did not differ among levels of Phosphorus and their interaction. This indicates that the germination and plant stand was uniform at all the levels of phosphorus application.

At harvest, the plant height, tiller number, dry matter recorded at 30 and 45 kg phosphorus ha^{-1} was comparable and significantly superior over 15 and 0 kg phosphorus ha^{-1}. The plant height, tiller number and dry matter observed in latter two levels of phosphorus application were comparable with each other.

Yield and Yield attributes

The phosphorus levels 30 and 45 kg ha^{-1} recorded higher spike length and 1000 grain weight which was comparable with each other and significantly greater than that of 0 and 15 kg phosphorus ha^{-1} levels. The spike length and 1000 grain weight observed in latter two levels of phosphorus was at par with each other. The number of spike lets and grains per spike increased significantly with increase in levels of phosphorus from 0 to 15, 30 and 45 kg ha^{-1}.

The grain and straw yield observed with 30 and 45 kg phosphorus ha^{-1} was comparable with each other and significantly superior over 0 and 15 kg phosphorus level. The grain and straw yield observed with latter two levels was comparable with each other.

The biological yield recorded at 30 and 45 kg phosphorus ha^{-1} levels was at par with each other and significantly superior over 15 kg phosphorus ha^{-1}. The biological yield observed with latter level of phosphorus was significantly greater than 0 kg ha^{-1} level of phosphorus.

The harvest index was higher at 0 level of phosphorus over that recorded with phosphorus application. The harvest index was similar with other three levels of phosphorus.

Phosphorus is the second limiting element after nitrogen for plant growth – plants cannot grow without a sufficient supply of this nutrient. Phosphorus plays an essential role in all physiological and biochemical processes in plants (Hartmann, 1977; Schachtman *et al.* 1998; Marschner 1999; Lott *et al.* 2000) [4, 8].

Significantly higher grain yield obtained with application of Phosphorus at 30 and 45 kg ha^{-1} as compared to 0 and 15 kg ha^{-1} might be due to increased levels of phosphorus application which results in greater concentration of it in plants that could help the plants to produce higher dry matter which is evident from the greater dry matter produced at higher levels of phosphorus (Table 3). In the present study, growth and yield components were significantly improved by phosphorus application. There was higher number of fertile tillers plant^{-}, spike lets spike^{-1}, and 1000-grain weight with phosphorus application. Significantly lower yield was obtained in crop that received 0, and 15 kg phosphorus ha^{-1} which can be attributed to lower values of the above-mentioned characters. Further, the grain yield had positive correlation with growth and yield attributing parameters (Table 4) indicating that improvement in yield attributes and growth in the crop that received higher levels of phosphorus resulted in higher grain yield. Seyed Ahmed Eftekhari *et al*., (2012) [9] reported that application of different phosphorus fertilizer rates significantly affected grain yield, P concentration and the total P content. The results showed that higher P application rates increased grain yield compared with the lower levels. The increased application of phosphorus fertilizer in the soil enhances the plant development of plant root system, improving plant nutrient absorption, especially P. This subsequently improves the plant leaf area, photo synthesis and thereby yields production (Colomb *et al.*, 2000) [3]. It was reported that the highest grain yield was obtained at phosphorus fertilizer level of 200 mg P_2O_5 per kg soil. The high level of 400 mg P_2O_5 per kg soil showed a negative effect on the productivity of barley grain and above ground biomass, but the differences were not significant with level 400 mg P_2O_5 per kg soil. Similar results were obtained for barley biomass productivity (Kostadinova, 2014) [5].

From this study, it can be concluded that growing of barley variety Super laxmi with 30 to 45 kg phosphorus ha^{-1} gives higher yield and monetary returns in gird region of northern Madhya Pradesh.

Table 1: Effect of Phosphorus levels on number of plants m^{-2}of barley varieties at ten days after sowing

Varieties	Number of plant m^{-2}	plant height at harvest, cm	Dry matter per plant (g)
NDB-2	42.00	89.50	13.87
Super Laxmi	42.08	96.08	14.79
NDB-1445	41.89	86.48	13.11
S.Em.±	0.28	2.12	0.31
CD at 5%	NS	6.31	0.94
Phosphorus Levels kg ha^{-1}			
0	42.08	83.22	10.85
15	42.21	84.35	11.60
30	41.93	95.23	16.03
45	41.74	99.95	17.21
S.Em.±	0.16	1.77	0.34
CD at 5%	-	6.94	1.34
Varieties and Phosphorus level			
S.Em.±	1.35	15.01	2.89
CD at 5%	NS	-	-

Table 2: Effect of varieties and Phosphorus levels on spike length, number of grains/ spike and spikelets/spike of barley varieties.

Treatment	Spike length (cm)	Number of grains/spike	Number of Spikelet /Spike	1000 grain weight (g)
Varieties				
NDB-2	7.52	46.95	56.84	35.21
Super Laxmi	7.65	47.52	57.90	35.64
NDB-1445	6.56	45.55	54.15	34.47
S.Em.±	0.24	0.41	0.75	0.17
CD at 5%	0.70	1.21	2.22	0.51
Phosphorus Levels, kg ha^{-1}				
0	6.70	42.84	52.77	33.84
15	6.89	45.97	55.04	33.95
30	7.55	48.18	57.47	35.72
45	7.83	49.70	59.91	36.92
S.Em.±	0.14	0.29	0.44	0.25
CD at 5%	0.55	1.14	1.73	0.96
Varieties and Phosphorus level				
S.Em.±	1.18	2.47	3.75	2.09
CD at 5%	-	-	-	-

Table 3: Effect of levels of Phosphorus on grain, straw and biological yield (kg ha^{-1}) and HI of barley varieties.

	Yield, kg ha^{-1}			
Varieties	**Grain**	**Straw**	**Biological**	**Harvest Index (%)**
NDB-2	2493	3057	5550	45.02
Super Laxmi	2643	3577	6220	42.60
NDB-1445	2305	2980	5285	43.77

S.Em.±	61	106	167	-
CD at 5%	181	315	496	-
Phosphorus Levels, kg ha^{-1}				
0	1940	2371	4311	45.07
15	2216	2714	4930	43.33
30	2734	3543	6277	43.58
45	3131	3990	7121	43.20
S.Em.±	80	118	198	-
CD at 5%	314	495	809	-
Varieties and Phosphorus level				
S.Em.±	678	1004	1682	-
CD at 5%	-	-	-	-

Table 4: Correlation between grain yield and growth and yield attributes

S/N	Characters	Correlation coefficient
1	Plant Height at harvest	0.85
2	Number of leaves per plant at 60 DAS	0.86
3	Number of effective tiller per m^2 at harvest	0.84
4	Dry weight per plant at harvest	0.88
5	Spike length	0.97
6	No. of grain per spike	0.99

Table value at 34 df at 5% = 0.326 Significant at 1% level

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