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Ravi Kumar Saini
Faculty of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, India

Mahipal Dudwal
Faculty of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, India

Pooran Mal Meena
Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India

Ayushi Saini
Faculty of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, India

Corresponding Author:
Ravi Kumar Saini
Faculty of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, India

Effect of sowing methods and nutrient management on growth, yield and quality of barley (*Hordeum vulgare* L.)

Ravi Kumar Saini, Mahipal Dudwal, Pooran Mal Meena and Ayushi Saini

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Abstract
A field experimented was conducted at Research Farm, Vivekananda Global University, Jaipur during *rabi* season of 2023-24 to study the effect of sowing methods and nutrient management on growth, yield and quality of barley. The results reveals that the Crisscross sowing along with application of 100% chemical fertilizers recorded significant improvement in growth, yield attributes and yield along with protein content in barley under the agro-climatic condition of Jaipur, Rajasthan.

Keywords: Crisscross, sowing, broadcasting, line sowing and vermicompost

Introduction
The barley cultivation in India suffered during green revolution period due to replacement of barley from marginal land and rainfed areas by more remunerative oilseed and pulses. However, during early nineties, due to economic liberalization, the industrial demand for barley increased and presently 25-30% of total barley produced is used in the manufacturing of malt extract, which is further utilized for brewing, distillation, baby foods, coca malt drinks and medicinal syrups. Barley yield will have to increase by 2.1 to 2.5% per year over the next 20 years to match the anticipated growth in population and to provide sufficient grain to meet a dramatic increase in the demand for animal feed. On the other hand, several yield reducing and yield limiting factors together with delayed sowing and rising cost of energy, labour, and other inputs are contributing to the stagnating or declining production, productivity and sustainability of the system.

To achieve the best possible coordination between soil moisture and temperature, sowing techniques should be improved. The sowing technique important because it affects how a crop stand should be established and producing individual plants requires balancing plant to plant combinations. Broadcasting, seed drilling, criss-cross, wide belt and furrow sowing are the main sowing techniques used to plant the barley crop, although other sowing techniques may have an impact on yield by changing how much water is used. While the line sowing method is recommended due to its uniform seed distribution and planting at desired depth, which typically leads in higher germination and uniform stand, broadcasting not only demands a larger seed rate but also results in lower or higher plant population.

Although cross and line sowing has generally been shown to be better to other sowing techniques, farmers are now compelled to scatter seed throughout the field due to rising costs. Inadequate time for land preparation, high labor costs, labor shortages, and a variety of other problems are also present. In fact, farmers are increasingly using seed broadcasting as a sowing technique. The conventional broadcast method was shown to be less effective than other seeding techniques in terms of barley production. Also, the cultural broadcast planting method affects whether each plant has access to enough space, which, in turn, affects how well it absorbs and uses resources like nutrients, moisture, sunlight etc. The low productivity may be caused by a number of production issues, including growing on marginal soils, using outdated seed sowing (planting) techniques, applying insufficient fertilizer, and planting crops too late, which subjects them to moisture stress. Planting technique is one of the main production-related restrictions.

Drilling produces a consistent population area^{-1}, it is also a preferred sowing technique. High germination and uniform stands are anticipated when seeds are planted at a consistent depth and covered with soil (Tanweer *et al.*, 2002) [12].

On the other hand, all Indian soil are low in available nitrogen, phosphorus and potassium. Balanced nutrition plays a major role in such condition for obtaining maximum yield and quality, to increase farm income, to avoid damage of environment to restore the soil fertility. Under various sowing methods the response of balanced nutrition gave better response in crop cultivation.

Materials and Methods

An experiment was conducted during *rabi* season of 2023-24 at Research Farm, Vivekananda Global University, Jaipur. The soil was loamy sand in texture having a pH of 8.3 (Alkaline), EC 1.1 (dS m^{-1}), low in organic carbon (0.14%) and low available nitrogen (132.7 kg ha^{-1}), medium in available phosphorus (16.3 kg ha^{-1}) and low in available potassium (150.4 kg ha^{-1}). The experiment was conducted in factorial randomized block design with replicate thrice consisted of sowing methods as first factor *viz*. (S_1) Line sowing at 22.5 cm, (S_2) crisscross sowing at 22.5 cm and (S_3) Broadcasting sowing and four nutrient levels as second factor *viz*. (F_1) 25% recommended dose through chemical fertilizers (CF) + 25% Vermicompost (VC) + 25% FYM + 25% Poultry manure (PM), (F_2) 50% recommended dose through chemical fertilizers + 25% Vermicompost + 25% FYM, (F_3) 75% recommended dose through chemical fertilizers + 25% Vermicompost and (F_4) 100% recommended dose through chemical fertilizers (120:60:60 kg NPK ha^{-1}). The treatments were allocated randomly to each plot. Urea, di ammonium phosphate and murate of potash were used as a source of nitrogen, phosphorus and potassium. The crop was fertilized as per treatment and a full dose of phosphorus and potassium as basal and nitrogen applied as basal as well as top dressing. Manures were applied one month before sowing. Sowing was done as per treatment. RD-2552 variety of barley was used as a test crop. Other crop management methods were accompanied as per the recommendation of the area.

Statistical analysis and interpretation of data: Data recorded on various parameters of barley crop in the experiment was subjected to analysis by using Fisher's method of analysis of variance (ANOVA) and interpreted as outlined by Gomez and Gomez (1984) [3]. The levels of significance used in 'F' and 't' test was p= 0.05. Critical difference values were calculated where F test was found significant.

Results and Discussion

Sowing methods and nutrient management practices exerted significant effect on growth characters, yield attributes, yield and protein content in barley. Crisscross sowing at 22.5 cm recorded significantly higher plant height (85.9 cm), number of tillers (377.0 m^{-2}), leaf area index (1.19) and dry matter accumulation (970.16 g m^{-2}) over rest of the sowing methods at harvest (Table 1). It is an established fact that uniform distribution of plants over cropped area with adoption of appropriate planting system and geometry facilitates efficient utilization of available growth inputs (above and below ground) for optimum growth and development of plants. Under the present investigation, marked improvement in nutritional status and photosynthetic efficiency (dry mater production) of plants when sown bi-directionally (cross) subscribe to the view that it is resultant of uniform distribution of plants over land area thereby ensuring more space per plant. Hence, in general, overall improvement in growth under cross-sowing seems to be due to higher availability of growth inputs (solar radiation and nutrients) and their efficient utilization and reduction in competition between plants for these growth inputs. The results of the present investigation are in close conformity with findings of several research workers. Pandey and Kumar (2005) [8] ascribed better growth and development of plants under cross sowing on account of uniform distribution of plants per unit area. While, Jat *et al*. (2004) [5] reported that increased area to individual plant under cross sowing provides favourable macro and micro environment for its growth.

In case of nutrient management practices, application of 100% chemical fertilizers (CF) recorded significantly higher plant height (86.1 cm), number of tillers (383.0 m^{-2}), leaf area index (1.20) and dry matter accumulation (978.12 g m^{-2}) over rest of the treatments at harvest (Table 1). This might have enhanced meristematic activity, thereby increased division, enlargement and elongation of cells resulting in higher plant height. Likewise, improvement in growth of buds metabolic and enzymatic reaction due to better nutritional conditions with balanced fertilization must have increased photosynthetic efficiency, resulting in higher production of dry matter. Since dry matter produced by plants is a result of biomass accumulated by each organ, the increased biomass of vegetative and reproductive parts ultimately enhanced total dry matter accumulation. The beneficial effect of balanced fertilization of primary nutrients (NPK) on plant height and dry matter accumulation by barley plants were also observed by several researchers (Islam *et al.*, 2002 and Dewal and Pareek, 2004) [4, 2].

Among the sowing methods, Crisscross sowing at 22.5 cm recorded significantly higher number of effective tillers (379.97 m^{-2}), ear length (9.33 cm) and number of grains spike^{-1} (37.28) and test weight (44.40 g) over rest of the sowing methods (Table 2). Marked improvement in yield attributes under cross sowing appears to be on account of vigorous growth of the plants as reflected by higher accumulation of dry matter m^{-2} at successive growth stages along with higher uptake of nutrients which subscribe to view that there was adequate supply of nutrients and metabolites under cross sowing for growth and development of each reproductive structure of the plants. In the barley crop besides environmental factors (climatic conditions), tillers formation and their growth and development is profoundly influenced by congenial internal environment (adequate supply of photosynthates and nutrients) to the plants. Inadequate supply to these growth inputs results in poor initiation of tillers due to depressed growth of lateral buds at early stage of crop growth. While at later stage, on account of competition between vegetative and generative parts for nutrients and metabolites, restricts tiller development and their transformation into effective tillers. The marked improvement in yield components under cross sowing was also reported by Kulhari (1999) [7] and Pandey and Kumar (2005) [8].

In case of nutrient management practices, application of 100% chemical fertilizers (CF) recorded significantly higher number of effective tillers (380.34 m^{-2}), ear length (9.38 cm) and number of grains spike^{-1} (38.12) and test weight (44.36 g) over rest of the treatments (Table 2). A faster growth rate in terms of dry matter production under the influence of balanced fertilization could be ascribed to significant role in adequate supply of photosynthates

for enhanced number of flowers and their fertilization resulting in higher number of filled spikelets and grain per ear. Further, in barley, greater assimilating surface at reproductive development might have resulted in better grain formation because of adequate production of metabolites and their translocation towards grain. It is evident from enhanced nutrient concentration and their uptake which could be reasoned for increased weight of individual grain expressed in terms of 1000 seed weight. Since grain weight per ear is dependent on number of grains per ear and weight of individual grains, thus highest grain yield per ear under application of recommended NPK could be ascribed to the improvement of these parameters. The results of present investigation indicating positive response of various yield parameters with application for balanced fertilization corroborates with the findings of Chaplot, 2000 [1]; Islam *et al.* (2002) [4]; Dewal and Pareek (2004) [2] and Verma *et al.* (2005) [13].

Among the sowing methods, Crisscross sowing at 22.5 cm recorded significantly higher grain yield (4417 kg ha^{-1}), straw yield (6587 kg ha^{-1}) and biological yield (11004 kg ha^{-1}) over rest of the sowing methods. However, harvest index was found to be non-significant (Table 3). Suthar (2006) [11] reported that increase in grain yield of barley crop with crisscross sowing was due to improvement in yield components. They further reported that increase in these yield attributes were due to better and efficient utilization of solar radiation and nutrients. Similarly, the investigations across the locations of NWPZ/CZ have clearly established superiority of crisscross sowing for input availability and utilization, reduced lodging and maintenance of better physical properties of soils. The recent studies under the auspices of AICWIP at several locations also indicated that there is no marked reduction in barley yield under this system but at the same time it facilitates several other advantages like reduction in input cost (seed/fertilizer/irrigation). However, under the present investigation, better macro and micro environment under crisscross sowing failed to offset inter plant competition thereby resulted in non-significant reduction in barley crop productivity over line sowing. The results of the present investigation indicating realization of higher yields under cross sowing over normal line sowing tend support to findings of previous studies (Singh and Kler, 2002 and Pandey and Kumar, 2005) [10, 8].

In case of nutrient management practices, application of 100% chemical fertilizers (CF) recorded significantly higher grain yield (4567 kg ha^{-1}), straw yield (6645 kg ha^{-1}) and biological yield (11212 kg ha^{-1}) over rest of the treatments. However, harvest index was found to be non-significant (Table 3). Dewal and Pareek (2004) [2] opined that balanced application of NPK improved nutritional environment of rhizosphere as well as plant system as evident from greater uptake of nutrients and ultimately metabolic and photosynthetic activity, resulting in better development of yield. The results of present investigation corroborates findings of previous researchers (Islam *et al.*, 2002 and Singh, 2004) [4, 9].

The data pertaining to protein content in grain are presented in Table 4. Among the sowing methods, significantly higher protein content (9.75%) was recorded with Crisscross sowing. The marked increase in protein content of grains produced by cross sown crop seems to be on account of higher concentration of N in the grains. Tanweer (2002) [12] also estimated higher protein content in grain under cross sowing over line sowing.

Application of 100% chemical fertilizers (CF) recorded significantly higher protein content (10.25%) in grain over rest of the treatments. Significant improvement in protein content can be partly reasoned to greater availability of nutrients on account of balanced fertilization and partly due to accelerating effect of these nutrients on protein synthesis as nitrogen is one of the integral constituent of protein and amino acid. Further, phosphorus fertilization improves the various metabolic and physiological process. In addition to this vital role, phosphorus is also a structural component of nucleic acid, phytin, phospholipids and enzymes. Whereas, K is not a structural part of any molecules but it necessary in protein synthesis. Enhancement in protein of barley grains by N and P application has also been reported by Zhao *et al.* (2003) [14] while, Kharub and Gupta (2003) [6] have reported positive influence of K application on protein content of barley grain.

Table 1: Growth characters of barley as influenced by sowing methods and nutrient management practices at harvest stage

Treatments	Growth characters at harvest			
	Plant height (cm)	No. of tillers (m^{-2})	Leaf area index	Dry matter accumulation (g m^{-2})
Methods of sowing				
Line sowing at 22.5 cm	78.0	353.0	1.02	892.28
Crisscross sowing at 22.5 cm	85.9	377.0	1.19	970.16
Broadcasting	69.0	327.5	1.14	945.93
S.Em±	1.9	8.0	0.03	17.91
LSD (*P = 0.05*)	5.5	24.0	0.09	51.48
Nutrient management				
25% CF + 25% FYM + 25% PM	68.0	327.0	1.04	887.07
50% CF + 25% VC + 25% FYM	74.6	333.5	1.09	917.54
75% CF + 25% VC	81.8	366.5	1.14	961.76
100% CF	86.1	383.0	1.20	978.12
S.Em±	2.1	9.0	0.04	17.89
LSD (*P = 0.05*)	6.1	25.5	0.13	51.27

Table 2: Yield attributes of barley as influenced by sowing methods and nutrient management practices

Treatments	Yield Attributes			
	No. of effective tillers (m^{-2})	Ear length (cm)	No. of grains $spike^{-1}$	Test weight (g)
Methods of sowing				
Line sowing at 22.5 cm	374.52	9.27	36.83	43.98
Crisscross sowing at 22.5 cm	379.97	9.33	37.28	44.40
Broadcasting	344.57	8.74	34.33	41.50
S.Em±	6.23	0.12	0.54	0.52
LSD (*P = 0.05*)	17.89	0.37	1.57	1.49
Nutrient management				
25% CF + 25% FYM + 25% PM	351.02	8.86	34.09	41.89
50% CF + 25% VC + 25% FYM	362.89	9.01	35.32	42.95
75% CF + 25% VC	371.16	9.23	37.06	43.97
100% CF	380.34	9.38	38.12	44.36
S.Em±	5.08	0.14	0.53	0.51
LSD (*P = 0.05*)	14.61	0.40	1.55	1.48

Table 3: Yield and harvest index of barley as influenced by sowing methods and nutrient management practices

Treatments	Yield			Harvest index (%)
	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	
Methods of sowing				
Line sowing at 22.5 cm	4276	6081	10357	41.29
Crisscross sowing at 22.5 cm	4417	6587	11004	40.14
Broadcasting	4025	6467	10492	38.36
S.Em±	84	137	162	0.95
LSD (*P = 0.05*)	241	392	478	NS
Nutrient management				
25% CF + 25% FYM + 25% PM	3889	6099	9988	38.94
50% CF + 25% VC + 25% FYM	4178	6148	10326	40.46
75% CF + 25% VC	4323	6421	10744	40.24
100% CF	4567	6645	11212	40.73
S.Em±	83	136	163	0.56
LSD (*P = 0.05*)	239	390	481	NS

Table 4: Protein content (%) in barley grain as influenced by sowing methods and nutrient management practices

Treatments	Protein content
Methods of sowing	
Line sowing at 22.5 cm	9.50
Crisscross sowing at 22.5 cm	9.75
Broadcasting	9.38
S.Em±	0.11
LSD (*P = 0.05*)	0.31
Nutrient management	
25% CF + 25% FYM + 25% PM	8.63
50% CF + 25% VC + 25% FYM	9.44
75% CF + 25% VC	9.88
100% CF	10.25
S.Em±	0.09
LSD (*P = 0.05*)	0.26

Conclusion

On the basis of one year experiment it may be concluded that Crisscross sowing along with application of 100% chemical fertilizers recorded significant improvement in growth, yield attributes and yield along with protein content in barley under the agro-climatic condition of Jaipur, Rajasthan.

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