Indian Journal of Agronomy **58** (3): 363–367 (September 2013)

Research Paper

Integrated use of fertilizers and manures with foliar application of iron in barley (*Hordeum vulgare*)

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Received : October 2012; Revised accepted : April 2013

ABSTRACT

A field experiment on integrated use of fertilizers and manures with foliar application of iron in barley {*Hordeum vulgare* (L.)} was conducted at Jobner on loamy sand soil during two consecutive *rabi* seasons of 2009–10 and 2010–11. Results of the study revealed that application of 50% RDF + VC @ 2 t/ha recorded significant increase in dry matter accumulation (DMA)/metre row length (364.5 g), yield attributes *viz*., spike length (10 cm), number of spikes/metre row length (81.6), grains/spike (48.9) and test weight (43.0 g) as well as grain (5.48 t/ha) and straw yield (7.85 t/ha). Application of 50% RDF + VC @ 2 t/ha also recorded significantly higher total uptake of N (111.1 kg/ha), P ((20.1 kg/ha), K (28.1 kg/ha), and Fe (8,399 g/ha) by barley. Application of 0.5% $FeSO_4$ as foliar spray at tillering + flowering stages resulted in significantly higher dry matter accumulation (342.1 g), higher yield attributes and grain (5.27 t/ha) and straw yield (7.37 t/ha) with higher total nutrient uptake. Interactive effect on grain yield was found significant between fertilizers, organic manure and foliar spray of iron. Application of 50% RDF + VC @ 2 t/ha along with foliar application of iron 0.5% $FeSO_4$ at tillering + flowering stage gave significantly higher yield over control.

***Key words*:** Foliar spray, Iron, Poultry manure, Recommended dose of fertilizers, Vermicompost

Barley, is an important *rabi* cereal crop in India. The major use of barley grain is in brewing industries for manufacturing malt, which is used to make beer and industrial alcohol. Its straw is used as fodder for cattle. Both barley grains and straw are highly digestible compared to wheat, because they do not contain glute in. Surplus barley grains are used as concentrate for livestock and poultry. Its straw and husk are good quality roughages for cattle and are used for preparing compost and litter bedding. Hence, there is great scope of recycling the crop waste in cattle and poultry enterprise. Barley grain contains 12.5% moisture, 11.5% albuminoids, 74.0% carbohydrate, 1.3% fat, 3.9% crude fibre and 1.5% minerals.

Farm yard manure supplies all the essential plant nutrients in small quantities and improves the physical, chemical and biological properties of the soil. The NPK content of poultry manure is much higher than that of FYM, because there is no urine loss since the solid and liquid are excreted together. Iron being an essential micronutrient takes active part in the metabolic activities of the plant. It acts as an activator of dehydrogenase, proteolase and peptidases enzymes and involved directly or indirectly in the synthesis of carbohydrates and proteins. Iron being a structural component of porphyrin molecules, cytochromes, heams, hematin, ferrichrome and leg–heamoglobin is involved in oxidation-reduction reactions. Iron in chloroplast reflects the presence of cytochromes for performing various photosynthetic reduction processes. The ferrodoxins are Fe–S proteins and are the first stable redox compound of the photosynthetic electron transport chain. As soil pH increases, the ionic form of iron changes to hydroxide form, which is insoluble and unavailable to plants. Therefore, spray of iron in the fields prone to the iron deficiency may be beneficial. The present investigation was carried out to identify the suitable combination of fertilizers and manures along with foliar application of iron in barley.

MATERIALS AND METHODS

A field experiment was conducted at Jobner during the *rabi* seasons of 2009–10 and 2010–11. The soil of the experimental field was loamy sand in texture, alkaline (pH 8.2), low in organic carbon (0.17–0.18), available N (128.68–131.72 kg/ha), Olsen's available P (6.3 kg/ha), medium in available K (132.6 kg/ha) and low in available Fe (2.20–2.25 mg/kg). The experiment was laid out in split

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plot design replicated thrice. The experiment consisted of 32 treatment combinations comprising of eight treatments of fertilizers and organic manures (No manure, 100% RDF, FYM @ 12 t/ha, poultry manure @ 5 t/ha, vermicompost @ 4 t/ha, 50% RDF + FYM @ 6 t/ha, 50% RDF + poultry manure @ 2.5 t/ha and 50% RDF + vermicompost @ 2 t/ha) in main–plots and four levels of $FeSO_4$ foliar spray (Control, tillering, flowering and tillering + flowering stage) in sub–plots. The nutrient content of different organic sources used in experiment was 0.45:0.22:0.50, 1.76:1.45:0.95 and 1.25:1.05:0.80% $N:P_2O_5:K_2O$ in FYM, vermicompost and poultry manure, respectively. The seeds of barley 'RD-2052' were sown at 22.5 cm row spacing using 100 kg seed/ha. The crop was sown on November 12, 2009 and November 15, 2010 and was harvested on March 23, 2010 and March 31, 2011, respectively. Fertilizers were applied as per treatments. The recommended dose of fertilizer for barley was taken as 60 kg N and 30 kg P_2O_5/ha. Full dose of P and half dose of N were applied as basal to the respective plots as per treatments. The source of N and P were urea and SSP respectively. The remaining half dose of N was applied at the time of first irrigation.

The nitrogen in samples was estimated by digesting plant samples with H_2SO_4 using hydrogen peroxide. Phosphorous content was estimated using vanadomolybdo phosphoric acid to develop yellow colour after wet digestion of plant samples (Jackson, 1973). Potassium content of samples was determined by flame photometer method (Metson, 1956). The data relating to each character were analyzed as per the procedure of analysis of variance as suggested by Panse and Sukhatme (1985). Economics of different treatments was worked out on the basis of input and output on the prevailing market prices and B:C ratio was calculated.

RESULTS AND DISCUSSION

Effect on dry matter accumulation

The dry matter accumulation/metre row length was significantly influenced by various combinations of fertilizers and organic manure treatments (Table 1&2). Application of 50% RDF with VC @ 2 t/ha, PM @ 2.5 t/ha and FYM @ 6 t/ha recorded significantly higher dry matter accumulation/metre row length at harvest over control, FYM @ 12 t/ha and PM @ 5 t/ha. Application of 50% RDF + VC @ 2 t/ha enhanced the dry matter accumulation by 61.1% at harvest over control (Table 1). The favourable effect of organic manure on growth was on account of improved photosynthetically active leaf area for longer period during vegetative and reproductive phases, leading to more absorption and utilization of radiant energy, which ultimately resulted in higher dry matter accumulation. Significant increase in dry matter accumulation per metre row length was observed with foliar spray of 0.5 % $FeSO_4$ as compared to control (water spray). Among foliar sprays, 0.5 % $FeSO_4$ foliar spray at tillering + flowering recorded

Table 1. Effect of fertilizers, organic manures and iron spray on dry matter accumulation (DMA)/metre row length (g), yield attributes, yield and economics of barley (Pooled data of two years)

Treatment	DMA at harvest	Spikes/ metre row length	Spike length (cm)	Grains/ spike Test	weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)	B:C ratio
Fertilizers and organic manures									
No manures	226.3	58.3	6.5	33.2	37.3	3.76	5.22	41.7	2.96
100% RDF	347.8	77.5	9.5	47.1	42.2	5.22	7.55	40.9	3.85
FYM @ 12 t/ha	311.8	67.7	7.9	41.8	40.4	4.54	6.55	40.9	3.21
P M @ 5 t/ha	313.6	70.3	9.0	46.4	42.0	5.11	7.39	40.8	3.10
VC @ 4 t/ha	343.4	77.2	9.2	47.2	42.3	5.13	7.43	40.8	2.52
50% RDF + FYM @ 6 t/ha	353.6	78.1	9.6	47.3	42.5	5.29	7.56	41.1	3.81
50% RDF + PM @ 2.5 t/ha	356.4	79.7	10.0	48.0	42.8	5.35	7.67	41.0	3.55
50% RDF + VC @ 2 t/ha	364.5	81.6	10.0	48.9	43.0	5.48	7.85	41.1	3.22
SEm±	6.4	1.6	0.3	1.0	0.4	0.17	0.17	0.4	0.09
CD (P=0.05)	18.4	4.6	0.8	2.8	1.1	0.50	0.50	NS	0.25
Foliar application									
Control	312.0	71.0	8.2	42.4	40.5	4.79	6.87	41.1	3.15
0.5% $FeSO_4$ spray at tillering	329.1	73.5	8.8	45.0	41.4	4.92	7.11	40.9	3.24
0.5% $FeSO_4$ spray at flowering	325.4	74.8	9.1	45.6	41.7	5.00	7.15	41.1	3.29
0.5% $FeSO_4$ spray at tillering + flowering	342.1	76.9	9.7	46.9	42.7	5.22	7.37	41.5	3.43
SEm±	3.5	0.5	0.1	0.3	0.2	0.03	0.04	0.1	0.02
CD (P=0.05)	9.7	1.5	0.2	0.8	0.6	0.08	0.11	NS	0.06

FYM–Farm yard manure; PM–Poultry manure; VC–Vermicompost; RDF–Recommended dose of fertilizer

highest value of DMA indicating an increase of 9.6% over control (Table 1). This might be due to readily available Fe at early and the critical stage of plant growth that facilitated maximum plant growth. Ibrahim and El–abban (1984) and Sakal *et al*. (1985) also held similar view on the rice plant growth.

Effect on yield attributes

Different yield attributes of barley were significantly increased by fertilizers and organic manure treatments (Table 1). Application of 50% RDF with VC @ 2 t/ha, PM @ 2.5 t/ha, and FYM @ 6 t/ha, 100% RDF and VC @ 4 t/ha recorded significantly higher number of spikes over control, FYM @ 12 t/ha and PM @ 5 t/ha. Spike length, grains/spike and test weight of barley were significantly improved by all treatments except FYM @ 12 t/ha over control. Contribution in supplying additional plant nutrients and increasing solubility of native soil nutrients could be the probable reason for efficient and increased partitioning of metabolites and adequate transformation of nutrients to developing plant structures. As a result, almost all yield attributes were significantly influenced by VC, PM and FYM alone and combined with 50% RDF, respectively. Kumawat (2003) observed significantly higher number of spikes/metre row length and spike length and number of grains per spike in barley due to application of VC @ 4.5 t/ha. The foliar applied $FeSO_4$ at 0.5% significantly increased the number of spikes/metre , spike length, grains/spike and test weight. Foliar application of 0.5% $FeSO_4$ at tillering + flowering stages of barley significantly increased the spikes/m row length (76.9), spike length (9.7 cm), grains/spike (46.9) and test weight (42.7 g) indicating an increase of 8.3, 18.3, 10.6 and 5.4%, respectively, over water sprayed control.

Grain and straw yields

A scrutiny of the data revealed that application of all treatments of fertilizers and organic manures recorded significantly higher grain and straw yields. Application of 50% RDF + FYM @ 6 t/ha, 50% RDF + PM @ 2.5 t/ha and 50% RDF + VC @ 2 t/ha being at par with each other recorded significant increase of 40.7, 42.3 and 45.7% in grain and 44.8, 46.9 and 50.4% in straw yield over control, respectively (Table 1). Fertilizers and organic manures could not produce any significant variation on the harvest index of barley. Application of 100% RDF recorded maximum B:C ratio registering an increase of 30.1% over control. It is well known that addition of vermicompost, poultry manure and FYM separately and combined with RDF could increase the micronutrient concentration in the soil and increase the adsorption power of soil for cations and anions particularly phosphates and nitrates and they were released slowly for the benefit of the crop during entire growth period. Sreeniwas *et al.*, (2000) opined that humic acid in VC enhanced the availability of both native and added micronutrients in soil and thus plant growth, yield attributes and yield were increased. Significant increase in grain and straw yield of maize with application of poultry manure up to 4.5 t/ha was reported by Subehia (1998). Similarly, Roy and Singh (2006) observed increased grain and straw yield with application of 10 t/ha vermicompost..

The foliar applied $FeSO_4$ at 0.5% significantly increased the grain and straw yield, wherein application at tillering + flowering stage gave maximum and significantly higher values of grain and straw yield. Foliar application of 0.5% $FeSO_4$ at tillering or flowering stages independently also recorded significantly higher yield over water spray. Foliar spray of $FeSO_4$ was found non significant with respect to harvest index. Whereas, at tillering+ flowering, it recorded an increase of 8.9% in B:C ratio over control. Foliar application of nutrient is a good way for supplying optimum nutrition for crop to complete its reproductive phases for obtaining higher productivity. The results of present investigation are in conformity with those of Sharma and Gupta (1986).

The interactive effect of fertilizers and organic manures with foliar application was found significant on the grain yield (Table 2). Increased yield was noted with RDF 50% + VC @ 2 t/ha than any other treatment, but was statistically at par with RDF 50% + PM @ 2.5 t/ha with 0.5% $FeSO_4$ foliar spray at tillering + flowering stage as well as 50% RDF+ FYM 6 t/ha, VC @ 4 t/ha and RDF 100%.

Table 2. Combined effect of fertilizers, organic manures and iron spray on grain yield (t/ha) of barley (Pooled data of two years)

Treatment	Foliar application (0.5% $FeSO_4$)			
	Control	Tillering	Flowering	Tillering + Flowering
No manure	3.50	3.61	3.68	4.15
100% RDF	5.08	5.18	5.25	5.39
FYM @12 t/ha	4.42	4.50	4.57	4.65
P M @ 5 t/ha	5.00	5.07	5.12	5.25
VC @ 4 t/ha	5.00	5.09	5.15	5.27
50% RDF + FYM @ 6 t/ha	5.17	5.23	5.31	5.45
50% RDF + PM @ 2.5 t/ha	5.23	53.1	5.39	5.45
50% RDF + VC @ 2 t/ha	5.34	5.38	5.52	5.69
	SEm±		CD (P=0.05)	
F at same level of M	0.8		2.3	
M at same or different level of F	1.0		2.8	

FYM–Farm yard manure; PM–Poultry manure; VC–Vermicompost; RDF–Recommended dose of fertilizer

Nutrient uptake

The total nutrient uptake of nitrogen, phosphorus, potassium and iron in barley was significantly influenced by the application of various combination of fertilizers and organic manures (Table 3). Higher uptake of NPK and Fe was recorded with the application of 50% RDF + VC @ 2.0 t/ha, followed by 50% RDF + PM @ 2.5 t/ha and 50% RDF + FYM @ 6 t/ha. Combination of FYM @ 6 t/ha, PM @ 2.5 t/ha and VC @ 2 t/ha with 50% RDF recorded a significant increase of 71.4, 73.4 and 80.1% in N uptake, 73.0, 76.6 and 81.1% in P uptake, 66.7, 69.1 and 73.5% in K uptake and 55.9, 57.4 and 61.7% in Fe uptake, respectively, over control. Foliar spray of 0.5% $FeSO_4$ at tillering + flowering significantly increased the N,P,K and Fe up-

Table 3. Effect of fertilizers and organic manures with application of iron on uptake of nitrogen, phosphorus and potassium (Pooled data of two years)

Treatment	N uptake (kg/ha)	P uptake (kg/ha)	K uptake (kg/ha))	Fe uptake (g/ha)
Fertilizers and organic manures				
No manure	61.7	11.1	16.2	5194
100% RDF	103.2	18.8	26.4	7925
FYM @ 12 t/ha	82.0	14.8	21.0	6686
P M @ 5 t/ha	101.2	18.3	25.5	7721
VC @ 4 t/ha	101.6	18.4	25.8	7770
50% RDF + FYM @ 6 t/ha	105.8	19.2	27.0	8098
50% RDF + PM @ 2.5 t/ha	107.0	19.6	27.4	8176
50% RDF + VC @ 2 t/ha	111.1	20.1	28.1	8399
SEm±	4.2	0.7	0.9	217
CD (P=0.05)	12.2	1.9	2.6	628
Foliar application				
Control	89.7	16.2	23.5	6983
0.5% $FeSO_4$ spray at tillering	94.7	17.2	24.3	7369
0.5% $FeSO_4$ spray at flowering	97.6	17.7	24.8	7532
0.5% $FeSO_4$ spray at tillering + flowering	104.7	19.1	26.1	8101
SEm±	1.0	0.2	0.3	77
CD (P=0.05)	2.7	0.5	0.7	214

FYM–Farm yard manure; PM–Poultry manure; VC–Vermicompost; RDF–Recommended dose of fertilizer

Table 4. Effect of fertilizers and organic manures with application of iron on post harvest soil nutrient organic carbon and available iron status (Pooled data of two years)

Treatment	Organic carbon (%)	Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)	Available Fe (mg/kg)
Fertilizers and organic manures					
No manure	0.16	122.8	12.1	119.2	1.38
100% RDF	0.19	128.8	14.4	132.7	1.60
FYM @ 12 t/ha	0.31	137.3	15.7	142.8	1.83
P M @ 5 t/ha	0.29	140.4	16.3	143.6	1.91
VC @ 4 t/ha	0.24	141.8	15.9	140.9	1.95
50% RDF + FYM @ 6 t/ha	0.26	133.6	14.1	137.0	1.71
50% RDF + PM @ 2.5 t/ha	0.25	134.8	14.7	137.0	1.79
50% RDF + VC @ 2 t/ha	0.22	136.9	14.3	135.8	1.79
SEm±	0.01	3.5	0.4	3.2	0.01
CD (P=0.05)	0.02	10.0	1.1	9.3	0.04
Foliar application					
Control	0.24	133.3	14.1	135.5	1.73
0.5% $FeSO_4$ spray at tillering	0.24	134.7	14.2	135.7	1.74
0.5% $FeSO_4$ spray at flowering	0.25	135.7	14.2	136.0	1.75
0.5% $FeSO_4$ spray at tillering + flowering	0.23	134.4	14.3	137.3	1.75
SEm±	0.001	0.9	0.1	0.8	0.01
CD (P=0.05)	NS	NS	NS	NS	NS

FYM–Farm yard manure; PM–Poultry manure; VC–Vermicompost; RDF–Recommended dose of fertilizer

take indicating an increase of 16.7, 17.9, 11.1 and 16.0%, respectively over control. This might be due to increased supply of Fe and good response by the plants leading to enhanced translocation of nutrients to reproductive structures *viz.*, spikes and grains. The significant response of barley to iron is due to low status of iron availability in experimental soil. The application of iron through foliar spray of 0.5% $FeSO_4$ had favourable effect on the absorption of various nutrients, which is supported by lower concentration of P and higher concentration of Fe in grain and straw. The results of present investigation are in agreement with those of Prasad *et al*. (1983).

Post-harvest soil nutrient status

Data reveal that fertilizer and organic manure treatment significantly increased organic carbon content in soil after harvest (Table 4). Organic source like FYM, PM and VC showed the higher enhancement in OC followed by their integration with 50% RDF. In case of available nitrogen, VC @ 4 t/ha recorded the highest value followed by PM @ 5 t/ha. Among the three organic manures alone and combined with RDF in the experiment, FYM recorded the highest OC content. Application of PM @ 5 t/ha resulted in the highest available P status of the soil. Organic matter has solubilising effect on some mineral compounds present in soil and brings about the conversion of a number of chemical elements to available form. The superiority of vermicompost in increasing the available N status might be due to presence of higher content of N and the beneficial microbes present in it. Organic manure on decomposition solubilise insoluble organic P fractions through release of various organic acids and increase the P status of soils. The available K content of soil before the experiment was of medium range and hence different organic manures performed equally good. Foliar spray of 0.5% $FeSO_4$ at any stage could not influence the post–harvest status of nutrients in soil.

Based on the study, it is concluded that for higher productivity, barley should be fertilized with 50% RDF + VC @ 2t/ha or PM @ 2.5 t/ha or FYM @ 6 t/ha along with foliar spray of 0.5% $FeSO_4$ at tillering + flowering.

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