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Effect of Integrated Nutrient Management on Growth, Yield, Soil Fertility and Economics of Barley (*Hordeum vulgare* L.)

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Abstract The maximum plant height (81.4 cm) at flowering stage, highest yield (38.8 q ha^{-1}) of dry matter at flowering stages, highest number of tillers (183.7) at jointing stages, nutrient concentration (N 2.21, P 0.456, K 0.835% and Zn 27.45 mg kg^{-1}) and grain and straw yield (45.59 and 66.69 q ha^{-1}) of barley was found maximum under 75% NPK fertilizers supplied in combination with 5 t FYM ha^{-1} + 20 kg $ZnSO_4$ ha^{-1} respectively. Maximum decline in soil pH was observed under (T_2) where only urea @ 80 kg N ha^{-1} was applied to both year crops. The highest organic carbon, microbial biomass carbon, available N, P, K content (0.49%, 92.6 mg kg^{-1}, 237.7, 19.9, 234.6 kg ha^{-1}) in soil was recorded with 75% NPK+ 5 t FYM ha^{-1} + 20 kg $ZnSO_4$ ha^{-1} (T_{10}) respectively followed by 50% NPK with 5 t FYM and 20 kg $ZnSO_4$ kg ha^{-1} was applied (T_8), after harvest of both the crops. Similar trend was observed in available micronutrients except zinc. The treatment T_{10} (75% NPK + 5 t FYM ha^{-1} + 20 kg $ZnSO_4$ ha^{-1}) was given highest net return up to Rs 37030 ha^{-1} with 2.68 B:C ratio.

Keywords *Hordeum vulgare* L., Growth, INM, Soil Fertility, Yield, Content.

Introduction

Barley (*Hordeum vulgare* L.) is an important *rabi* cercal crop in the Northern plains of India comprising the states of Uttar Pradesh, Haryana, Rajasthan, Punjab, Madhya Pradesh and Uttaranchal. The states of Uttar Pradesh, Rajasthan and Bihar account for about 52, 18 and 11% of the total area, respectively. The crop needs less water and is more tolerant to salinity and alkali condition than other winter cereals. The crop possesses very high tolerance to drought and salt. In India, barley is cultivated in an area about 0.70 m ba producing nearly 1.40 mt of grain with productivity of 2120 kg/ha. Organic manures, which were perhaps the major sources of plant nutrients in traditional agriculture, received less emphasis with the advent of high analysis chemical fertilizers. Without detracting from the fact that chemical fertilizer will continue to be main instrument for quickening the pace for agricultural production the recent researches, indicate that a judicious combination of organic manures and fertilizers can better maintain the ling-term

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soil fertility and sustain high levels of productivity. Therefore, use of both organic manure and chemical fertilizers in appropriate proportion assume special significance as complementary and supplementary to each other in crop production.

Materials and Methods

A field study was carried out during *rabi* season at the research farm of R.B. S. College, Bichpuri, Agra (UP). The soil was sandy loam in texture, low in organic carbon (3.2 g kg^{-1}), available nitrogen (194.7 kg ha^{-1}), moderate in phosphorus (14.8 kg ha^{-1}) and potassium content (212 kg $ha^{-1)}$, with a slight alkaline in reaction (pH-8.05). The experiment was laid out in randomized block design with 10 treatments and three replications. Ten treatments were T_1 (control), T_2 (100% N), T_3 (100% NP) T_4 (100% NPK), T_5 (75% NPK), T_6 (50%, NPK), T_7 (50% NPK) + 20 kg $ZnSO_4$ ha^{-1}, T_8 (50% NPK) + 5 t FYM ha^{-1} + 20 kg $ZnSO_4$ ha^{-1}, T_9 (75% NPK) + 20 kg $ZnSO_4$ ha^{-1} and T_{10} (75% NPK) + 5 t FYM ha^{-1} + 20 kg $ZnSO_4$ ha^{-1}. The whole amount of P, K, and $ZnSO_4$ was applied as basal dressing and N was applied 50% basal, 25% at tillering stage and 25% at ear initiation. FYM was applied 15 days before sowing the barley as per treatments. The EC was determined in clear supernatant liquid with Conductivity Bridge by conductivity meter. pH was measured with the help of a pH meter [1]. Soil microbial biomass carbon (SMBC) was estimated using chloroform fumigation incubation method [2]. Available nitrogen in soil was determined by alkaline permanganate method [3]. Available phosphorus in soil was determined by ascorbic acid blue color method [4]. Available potassium was extracted with neutral NH_4OAc. The potassium in the extract was determined with flame photometer. Available Zn, Fe, Cu and Mn were extracted with DTPA solution buffered at pH 7.3 [5] and determined with atomic absorption spectrophotometer. Nitrogen content in grain and straw was determined by modified Kjeldahl method. Oven dried grain and straw samples were digested in mixture of HNO_3 : $HClO_4$ (3 :1) and P and K were determined by adopting standard methods [1]. Zinc in the acid extract was determined on atomic absorption spectrophotometer [5].

Results and Discussion

Plant growth

The effect of FYM with 75% dose of NPK + 20 kg $ZnSO_4$ ha^{-1} (T_{10}) was found superior to 100% NPK (T_4) alone. Maximum plant height (32.2 and 31.3 cm) was observed with T_{10} during 2009 and 2010 respectively (Table 1). Lowest plant height 20.5 and 20.6 cm

Table 1. Effect of integrated nutrient supply system on plant height, number of tillers and dry matter accumulation at different stages of barley crop (pool of two years).

Treatments	Plant height (cm)			Number of tillers/meter row length			Dry matter accumulation (q/ha)		
	Tillering	Jointing	Flowering	Tillering	Jointing	Flowering	Tillering	Jointing	Flowering
T_1- Control	20.6	50.6	63.4	72.2	112.5	89.0	2.4	21.5	28.9
T_2-80 kg N ha^{-1}	22.7	58.1	67.3	76.3	141.0	96.3	2.6	25.6	34.6
T_3-80 kg N, 40 kg P_2O_5 ha^{-1}	23.9	60.0	71.7	77.3	144.8	97.0	2.6	26.6	35.7
T_4-100% RD of NPK (80: 40:40 kg ha^{-1})	30.3	71.2	79.6	86.0	177.8	110.8	2.9	30.2	37.6
T_5-75% NPK (60:30:30 kg NPK ha^{-1})	25.1	65.8	74.2	81.8	165.8	101.5	2.7	27.5	36.3
T_6-50% NPK (40::20:20 kg NPK ha^{-1}	24.1	55.1	66.2	75.0	130.0	91.8	2.4	23.6	31.8
T_7-50% NPK+20 kg $ZnSO_4ha^{-1}$	23.4	58.7	66.3	76.2	133.7	94.0	2.5	24.8	33.7
T_8-50% NPK+5t FYM ha^{-1}+20 kg $ZaSO_4$ ha^{-1}	24.2	64.3	74.1	80.3	156.7	98.7	2.7	27.5	36.3
T_9-75% NPK+20kg $ZaSO_4$ ha^{-1}	29.3	69.2	77.7	84.2	172.0	105.5	2.8	28.8	36.6
T_{10}-75% NPK+5t FYM ha^{-1}+ 20 kg $ZnSO_4$ ha^{-1}	31.7	73.2	81.4	87.3	183.7	116.3	3.4	31.7	38.8
CD (p=0.05)	4.3	5.0	4.0	3.2	3.5	4.6	0.2	2.2	2.2

Table 2. Effect of integrated nutrient management on yield and nutrient concentration in grain and straw of barley crop.

Treatments	Yield (q/ha)		Nutrient content in Grain (%)				Nutrient content to Straw (%)			
	Grain	Straw	N	P	K	Zn (mg/kg)	N	P	K	Zn (mg/kg)
T_1-Control	29.15	51.79	1.84	0.307	0.515	17.42	0.285	0.03	1.455	12.91
T_2-80 kg N ha^{-1}	33.95	55.64	1.9	0.335	0.545	20.25	0.31	0.038	1.945	17.08
T_3-80 kg N,40 kg P_2O_5 ha^{-1}	35.39	58.17	2.06	0.343	0.605	22.14	0.345	0.038	2.01	17.43
T_4-100% RD of NPK (80:40:40 kg ha^{-1})	43.12	64.22	2.12	0.432	0.775	23.3	0.41	0.05	2.345	18.57
T_5-75% NPK (60:30:30 kg NPK ha^{-1})	38.71	61.79	2.08	0.374	0.67	22.17	0.35	0.045	2.205	17.19
T_6-50% NPK (40:20:20 kg NPK ha^{-1})	32.67	55,14	1.94	0.322	0.655	18.85	0.295	0.033	1.905	17.34
T_7-50% NPK+20 kg $ZnSO_4$ ha^{-1}	32.77	56.2	1.84	0.338	0.625	23.54	0.32	0.035	1.935	19.68
T_8-50% NPK+5 t FYM ha^{-1}+20 kg $ZnSO_4$ ha^{-1}	38.3	61.66	2.06	0.361	0.685	23.65	0.325	0.041	2.195	21.05
T_9-75% NPK+20 kg $ZnSO_4$ ha^{-1}	41.14	62.96	2.1	0.411	0.745	24.24	0.38	0.047	2.33	21.01
T_{10}-75% NPK+5t FYM ha^{-1}+20 kg $ZnSO_4$ ha^{-1}	45.59	66.69	2.21	0.456	0.835	27.45	0.48	0.054	2.41	22.65
CD (p=0.05)	1.11	1.2	0.17	0.023	0.061	3.06	0.534	0.011	0.09	3.1

were noted during 2009 and 2010, respectively under T_1 treatment. Similar findings were also found by Pareta et al. [6]. The maximum plant height i.e. 81.4 cm was observed under treatment T_{10} and minimum i.e.63.4 cm was noted under control (T_1) during 2010 at flowering stage, respectively. Hence, it may be generalized that the significantly maximum plant height of barley was obtained with 75% NPK+ 5 t FYM ha^{-1} + 20 kg $ZnSO_4$ ha^{-1} (T_{10}) treatments. Similar results were observed by Gaur et al. [7]. The incorporation of organic source with inorganic fertilizer levels and zinc sulfate proved more beneficial regarding dry matter accumulation. It was observed that the treatment. T_{10} was also found highly effective in dry matter accumulation at flowering stage over rest of the treatments. Similar results were observed by Kumawat et al. [8].

Yield and content of grain and straw

Grain and straw yield of barley increased significantly with increasing levels of NPK fertilizers over control. Maximum grain (45.59 q ha^{-1}) and straw (66.69 q ha^{-1}) yields were obtained with T_{10}, which was significantly higher over the rest of the treatments (Table 2). Grain yield increased by 5.73% with 75% NPK + 5 t FYM ha^{-1} + 20 kg $ZnSO_4$ ha^{-1} treatment in comparison to T_4 (100% NPK) treatment. It is quite clear that 75% NPK + FYM + $ZnSO_4$ increased the yield of barley by 6.88 and 2.47 ha^{-1} (17.77 and 5.73%) as compared to the grain yield of barley with 75% and 100% NPK fertilizers alone, respectively. The grain yield increased by 4.00% with 75% NPK + 5 t FYM ha^{-1} + 20 kg Zn SO_4 ha^{-1} treatments in comparison to 100% NPK tretment, similar findings observed by Katiyar and Uttam [9]. Similarly, 7.93% enhancement in straw yield was noted with 75% NPK + 5 t FYM ha^{-1} + 20 kg $ZnSO_4$ ha^{-1} treatments over 75% NPK alone.

Nitrogen content of grain and straw of barley was found more effective with treatment T_4 (100% NPK) in enhancing the nitrogen content (2.12% and 0.410%) in grain and straw of barley as compared to rest treatments except T_{10}. (2.21 and 0.480%) during both the years. The highest concentration of nitrogen in grain and straw of barley was found with T_{10} (75% NPK + 5 t FYM ha^{-1} + 20 kg $ZnSO_4$ ha^{-1}) treatment. The maximum concentration was recorded to the extent of 0.45% with T_{10} (75% NPK + FYM + $ZnSO_4$). Similar trend was found in case of straw of barley crop. The crop fertilized with T_{10} (75% NPK + FYM +$ZnSO_4$) raised significantly the concentration of potassium in grain and straw over T_4 (100% NPK) and T_9 (75% NPK) + 20 kg Zn SO_4 ha^{-1}. The maximum K-content was recorded at T_{10} (75% NPK + 5 t FYM + 20 kg $ZnSO_4$) treatment during both the years. The minimum K-contents (0.520 and 0.510%) in grain were noted in 2009 and 2010 respectively with control. The

Table 3. Effect of integrated nutrient management on fertility status of soil after harvesting the barley crop (pool of two years).

Treatments	pH	OC (%)	SMBC (mg/kg)	Available (kg/ha)			Available micronutrients (mg/kg)			
				N	P	K	Zn	Fe	Cu	Mn
T_1- Control	8.0	0.40	48.2	180.6	10.7	195.1	0.54	15.16	1.19	5.24
T_2- 80 kg N ha^{-1}	7.5	0.41	58.6	192.0	11.6	196.8	0.58	15.60	1.36	5.44
T_3-80 kg N, 40 kg P_2O_5 ha^{-1}	7.6	0.42	62.2	200.4	15.3	198.1	0.62	15.72	1.37	5.47
T_4-100% RD of NPK (80:40:40 kg ha^{-1})	7.7	0.46	74.4	221.5	19.2	226.7	0.67	16.21	1.47	5.64
T_5-75% NPK (60:30:30 kg NPK ha^{-1})	7.8	0.43	68.5	208.9	17.2	217.8	0.65	16.02	1.43	5.58
T_6-50% NPK (40:20:20 kg NPK ha^{-1})	7.9	0.42	60.8	184.7	16.3	212.7	0.66	15.52	1.32	5.25
T_7-50% NPK+20 kg $ZnSO_4$ ha^{-1}	7.8	0.42	61.2	186.6	16.9	215.0	0.68	15.56	1.33	5.42
T_8-50% NPK+ 5 t FYM ha^{-1}+20kg $ZnSO_4ha^{-1}$	7.9	0.48	90.8	204.0	17.4	218.3	0.71	15.91	1.40	5.51
T_9-75% NPK+20 kg $ZnSO_4$ ha^{-1}	7.7	0.44	70.4	212.9	18.1	225.5	0.70	16.16	1.45	5.61
T_{10}-75% NPK+5 t FYM ha^{-1}+20 kg $ZnSO_4$ ha^{-1}	7.8	0.49	92.6	237.7	19.9	234.6	0.73	16.31	1.49	5.68
CD (p=0.05)	NS	0.04	14.2	13.5	1.0	12.2	0.11	0.04	0.02	0.17

treatment T_{10} (75% NPK+FYM + $ZnSO_4$) was found best in case of K content of barley straw. In case of zinc content in grain and straw of barley crop, maximum content of zinc 27.45 mg/kg and 22.65 mg/kg respectively was noted under T_{10} (75% NPK + 5 t FYM+ 20 kg $ZnSO_4$) in grain and straw, 2009 and 2010 and minimum zinc content (17.42 and 12.91 mg/kg) was found under control.

Soil pH and organic carbon

The soil pH after harvest the crop slightly declined in all the treatments except in control (Table 3). Maximum decline in soil pH was observed under (T_2) where only urea @ 80 kg N ha^{-1} was applied to both year crops. The minimum decrease in soil pH was observed in treatments where FYM used in the form of organic source of nutrients. The percentage of organic carbon in the soil was significantly higher than initial status under almost all the INM treatments. Organic carbon content varied from 1.71 to 21.2% over control due to application of FYM. Kumar and Singh [10] also reported that FYM is the best source to build up of organic carbon.

Availability macronutrients in soil

Integrated nutrient management in barley influenced the available N in the soil. Available N content in soil was found maximum with T_{10} (75% NPK+FYM +$ZnSO_4$ after harvesting of barley crop. The data indicate that the response due to INM treatments varied from 2.29 to 31.62%, over the control. Application of FYM and 75% RDF recorded significantly higher available P than 100% RDF and rest of the treatments. Highest phosphorus availability of 34.5% over initial value was recorded in T_{10}. Addition of FYM with inorganic fertilizer had a beneficial effect in increasing the phosphate availability, which was also observed Yaduvanshi and Sharma [11]. An increasing trend in potassium availability was noted with the increase in the level of chemical fertilizers. The higher potassium availability was recorded under combined application of organic and inorganic nutrient sources as compared to inorganic fertilizers alone.

Soil microbial biomass carbon in soil

Application of different INM treatments showed a significant impact on microbial biomass carbon of soil (Table 3) after the harvest of both the year crops. The SMBC in soil varied from 48.2 to 92.6 mg kg^{-1} after harvest of both season crops. The highest microbial biomass carbon content in soil was recorded from the 75% NPK + 5 t FYM ha^{-1} + 20 kg $ZnSO_4$ ha^{-1} (T_{10}) followed by 50% NPK with 5 t FYM and 20 kg $ZnSO_4$ kg ha^{-1} was applied (T_8), after harvest of both the crops. Increase in microbial biomass carbon both sea-

Table 4. Effect of different organic and inorganic sources application on economics of barley crop.

Treatments	Cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	Benefit cost ratio (Rs/ha)
T_1 - Control	10780	34810	24030	2.23
T_2 - 80 kg N ha^{-1}	11720	39368	27648	2.36
T_3 - 80 kg N, 40kg P_2O_5 ha^{-1}	12845	41084	28239	2.2
T_4 - 100% RD of NPK (80:40:40 kg ha^{-1})	13280	48394	35114	2.64
T_5 - 75% NPK (60:30:30 kg NPK ha^{-1})	12584	44479	31895	2.53
T_6 - 50% NPK (40:20:20 kg NPK ha^{-1})	11983	38286	26403	2.2
T_7 - 50% NPK+ 20 kg $ZnSO_4$ ha^{-1}	12483	38874	26391	2.11
T_8 - 50% NPK + 5 t FYM ha^{-1} + 20 kg $ZnSO_4$ ha^{-1}	13233	44135	30902	2.34
T_9 - 75% NPK+ 20 kg $ZnSO_4$ ha^{-1}	13084	46541	33457	2.56
T_{10}- 75% NPK+ 5 t FYM ha^{-1}+20 kg $ZnSO_4$ ha^{-1}	13834	50864	37030	2.68

son crops might be due to the added effect of FYM, that led to increase in microbial population in soil. Findings of Rao [12] supported such results.

Availability micronutrients in soil

The amount of available Zn, Fe, Cu and Mn (0.73, 16.31, 1.47 and 5.68 mg kg^{-1}, respectively) were maximum with 75% NPK + 5 t FYM ha^{-1} + 20 kg $ZnSO_4$ ha^{-1} in (T_{10}) followed by 50% NPK + 5 t FYM ha^{-1} + 20 kg $ZnSO_4$ ha^{-1} (T_8). This may be due to formation of organic chelates, which decreased their susceptibility to adsorption, fixation and precipitation resulting in their enhanced availability in soil, [13]. Increasing in available Fe and Mn with the increasing dose of fertilizer may be due to lowering of pH which is known to increase the solubility of metallic elements. Available Fe, Cu and Zn were significantly higher in (T_{10}) 75% NPK + 5 t FYM ha^{-1} + 20 kg $ZnSO_4$ ha^{-1} over control [14].

Economics

The net return and B: C ratio varied with the various treatments. Among the INM treatments, treatment T_{10} (75% NPK + 5 t FYM ha^{-1} + 20 kg $ZnSO_4$ ha^{-1}) resulted in highest net return up to Rs 37030 ha^{-1} with 2.68 benefit : cost ratio. The net return was received from T_{10} (75% NPK + 5 t FYM ha^{-1} + 20 kg $ZnSO_4$ ha^{-1}) Rs 5135 and Rs 1916 ha^{-1} over T_5 (75% NPK) and T_4 (100% NPK) treatments, respectively (Table 4). Lowest net return (Rs 24030) and 2.23 B:C ratio were obtained with control. The economic of applied organic manures like FYM along with NPK and $ZnSO_4$ has been reported by Kumar and Singh [10].

Under barley cropping system, combined application of 75% NPK through inorganic fertilizer source and 5 t well decomposed FYM with 20 kg zinc sulfate per hectare was found to be beneficial in increasing the productivity of crop and improving soil fertility status as compared to sole application of chemical fertilizers.

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