Indian Journal of Agronomy **55** (2): 114–118 (June 2010)

Planting systems and integrated nutrient management for enhanced wheat (*Triticum aestivum*) productivity

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Received: May, 2008

ABSTRACT

A field experiment was conducted during the *rabi* 2004-05 and 2005-06 on sandy loam soil to assess the effect of ten integrated nutrient management practices (INM) under two planting systems [conventional and furrow irrigated raised bed (FIRB)] on wheat (*Triticum aestivum* L. emend. Fiori & Paol.). The results revealed that FIRB planting registered higher mean spikes/m2, grains/spike and 1,000-grain weight resulting in 8.6% higher grain yield than conventional planting (4.36 tonne/ha). The higher grain and biological yield of wheat in FIRB planting led to higher NPK uptake, however, post harvest available NPK status of soil did not vary among two planting systems. The application of fertilizers (inorganic alone or inorganic with FYM) recorded significantly higher mean yield attributes and grain yield over control. Recommended dose of fertilizers (RDF) i.e. 120-26.4-50 kg N-P-K/ha along with 5 tonne FYM/ha + Biofertilizer (*Azotobacter,* PSB and VAM) + 25 kg ZnSO4/ha produced higher yield attributes resulting in 22% more grain yield than RDF (4.14 tonne/ha). The higher yield led to higher NPK uptake by wheat. Further, the available NPK content of soil also increased in above INM treatment over control. Highest net returns (Rs 27,067) were obtained in FIRB planting and with recommended dose of fertilizers + 5 tonne FYM/ha + Biofertilizer + 25 kg $ZnSO_4$/ha.

Key words*: Azotobacter,* Farmyard manure, Organic fertilizers, Wheat, Zinc, Yield

Wheat (*Triticum aestivum* L. emend. Fiori & Paol.) is very important and remunerative *rabi* crop of North India. It is the second most important cereal crop after rice, grown under diverse agro-climatic conditions on 28 m ha area in India with a production of 76 m tonnes (Economic Survey, 2006-07). Wheat is an exhaustive crop of soil nutrients. The deteriorating soil health, declining soil organic matter and increase of micronutrient deficiencies has put a big question mark on the sustainability of wheat production. Planting of crop on raised beds, usually 70 to 90 cm wide, with 2-3 rows on top of each bed, the furrows between the beds are used for irrigation water application. With this system, the emerging wheat plants form a solid stand in the space between the irrigation furrows. This system does allow the use of furrow for irrigation, which provides better water management and reduce seed rate than the conventional flat bed planting (Jat, 2005). Integrated nutrient management (INM) along with modified land configuration technologies like furrow irrigated raised bed (FIRB) planting could help in mitigating the problem to some extent. Since variation in planting pattern modifies macro and micro-environment to which plants are exposed FIRB planting have the potential to improve the productivity of wheat. The potential sources of nutrients include chemical fertilizers, bulky organic manures and biofertilizers. Integrated nutrient management enhances both uptake of nutrient by wheat crop and availability of soil nutrients during growing seasons of crops. Such a system of nutrient management using all available sources to meet the crop needs in an integrated manner under different planting system was the focal attention under present investigation.

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MATERIALS AND METHODS

The field experiment was carried out at the research farm of Division of Agronomy, Indian Agricultural Research Institute, New Delhi located at $28^0 48'$N latitude and $77^0 12'$E longitude at an altitude of 228.61 above mean sea level during *rabi* 2004-05 and 2005-06 at a new site in each year. The soil was sandy loam with pH 7.3 and 7.2 (1:2.5 soil to water), organic carbon 0.37 and 0.38%, available N 155.5 and 160.4 kg/ha available K 162.1 and166.3 kg/ha and available P 9.7 and 10.1 kg/ha at the start of the experiment in 0 to 30 cm soil layer during 2004-05 and 2005-06, respectively. The treatments consists of two planting systems (conventional and FIRB) and

10 fertility treatments viz., control, recommended dose of fertilizers (RDF) i.e. 120-26.4-50 kg N-P-K/ha, 75% RDF + Farmyard manure (FYM 5 tonne/ha), 75% RDF + FYM + Zn, 75% RDF + FYM + Biofertilizer (BF), 75% RDF + FYM + BF + Zn, RDF + FYM, RDF + FYM + Zn, RDF + FYM + BF and RDF + FYM + BF + Zn. The study was made in factorial randomized block design with three replications. In FIRB system, 15 cm high and 45 cm broad bed with a furrow width of 25 cm between the beds was prepared with planting three rows of wheat in rows 15 cm apart (Jat *et al.*, 2005). Half dose of N and full dose of P and K through urea, single super phosphate and muriate of potash, respectively were applied at sowing and remaining N was applied after first irrigation. Farmyard manure @ 5 tonne/ha containing 0.49-0.37-0.55% N-P-K was applied one month prior to sowing. The biofertilizers viz., *Azotobacter chroococcum*, phosphate solubulizing bacteria (PSB) i.e. *Pseudomonas striata* were used to inoculate the seed while mixed culture of Vesicular Arbuscular Mycorrhiza (VAM) was applied directly to soil in rows during sowing. Zinc sulphate ($ZnSO_4$) was applied @ 25 kg/ha as a basal dose. Wheat 'HD 2285' was sown on 30 November and 27 November and harvested on 10 April and 7 April, in 2005 and 2006, respectively. Other management practices were adopted as per recommendations of the crop under irrigated conditions. The nutrient uptake by the crops was obtained as product of nutrient concentration and yield.

RESULTS AND DISCUSSION

Yield attributes

Yield attributes *viz.* spikes/m^2 and grains/spike were significantly higher in FIRB than traditionally sown wheat (Table 1). The higher yield attributes of FIRB planting may be ascribed to higher dry matter production and translocation and the conversion of photosynthates in to reproductive parts. Fine tilth and better aeration causing less penetration impedance was responsible for better root development there by producing higher yield attributes. Similar beneficial effect of bed planting on yield attributes of wheat has been reported by Kumar *et al.* (2004), Jani *et al.* (2008) and Deshmukh *et al.* (2007).

Integrated use of fertilizers with FYM and biofertilizers increased the number of spikes/m^2, grains/spike and the test weight. The enhanced early vegetative growth in terms of higher leaf area index, dry matter accumulation and vigorous root system resulted in more spike which consequently increased the number of spike bearing tillers significantly. The combined application of 75% RDF or RDF along with FYM, biofertilizers and zinc also increased the grains/spike (Table 1). Stimulated vegetative growth of wheat on account of adequate and prolonged supply of essential nutrients in treatments receiving FYM, biofertilizers and zinc in addition to 75% RDF or RDF manifested itself in increased number of effective tillers, grains/spike and test weight. Similar beneficial effect of

Table 1. Effect of planting system and integrated nutrient management on dry matter accumulation (DMA), yield attributes and yield (t/ha) of wheat

Treatment	DMA 90 DAS	Spikes/m^2		Grains/spike		Test weight	Grain yield		Biological yield	
	(g/m^2)*	2004-05	2005-06	2004-05	2005-06	(g)*	2004-05	2005-06	2004-05	2005-06
Planting system										
Conventional	565.1	239.0	248.3	36.0	38.0	42.4	4.24	4.47	10.31	10.96
FIRB	644.1	268.9	275.7	38.0	40.5	44.0	4.52	4.94	10.95	11.91
SEm±	7.4	3.4	3.3	0.4	0.6	0.8	0.08	0.09	0.19	0.29
CD (P=0.05)	21.3	9.6	9.4	1.3	1.6	NS	0.23	0.26	0.59	0.89
Nutrient management										
Control	392.8	185.4	196.4	29.2	31.9	41.2	2.60	3.02	6.79	7.93
RDF	578.7	242.7	249.2	35.2	36.9	42.4	4.00	4.28	9.68	10.40
75% RDF+FYM	599.0	249.4	252.6	36.0	38.1	43.0	4.31	4.67	10.28	11.15
75% RDF+FYM+Zn	622.6	254.5	268.3	37.4	39.2	43.2	4.44	4.78	10.89	11.57
75% RDF+FYM+BF	629.6	263.1	273.4	38.8	41.2	43.6	4.70	5.03	11.28	12.13
75% RDF+FYM+BF+Zn	660.2	273.7	281.0	41.2	41.8	44.3	4.84	5.22	11.60	12.61
RDF+FYM	618.1	258.2	266.5	36.9	39.3	43.4	4.47	4.85	10.77	11.57
RDF+FYM+Zn	626.1	266.8	272.4	37.6	39.6	43.5	4.66	4.89	11.24	11.90
RDF+FYM+BF	652.8	272.5	278.0	39.1	43.2	43.8	4.83	5.18	11.71	12.48
RDF+FYM+BF+Zn	666.2	273.1	282.4	40.0	42.3	43.9	4.93	5.25	12.04	12.71
SEm±	16.6	7.5	7.3	1.0	1.3	1.9	0.18	0.20	0.41	0.52
CD (P=0.05)	46.6	21.5	20.9	2.8	3.6	NS	0.50	0.58	1.21	1.55

RDF: Recommended dose of fertilizers (120-26.4-50 kg N-P-K/ha); FYM: 5t/ha; Zn: 25 kg $ZnSO_4$/ha ; BF: Biofertilizers ; *Pooled data

INM on yield attributes of wheat has been reported by Sharma *et al.* (2009).

Yield

The dry matter accumulation at 90 days after sowing (DAS), grain and biological yield of wheat vary significantly due to planting systems. Dry matter accumulation at 90 DAS, grain and biological yield were significantly higher under FIRB planting (Table 1). The FIRB planting registered a 6.6 and 10.5% higher grain yield over conventional system during 2004-05 and 2005-06, respectively. Higher grain yield with bed planting of wheat has been also reported by Kumar *et al.* (2004) and Chauhan *et al.* (2000). The increase in grain yield of wheat under FIRB could be attributed to higher yield attributes whereas, the increase in biological yield was due to higher plant height, dry matter accumulation. Higher grain and biological yield recorded in FIRB planting can also be attributed to better soil environment in ridges since prolonged ponding reduces yield.

On perusal of data on the grain yield of wheat, significant superiority of treatments receiving RDF or RDF in combination with FYM was observed over the unfertilized control during both the years of study (Table 1). Among different treatments, the treatment where RDF was applied in combination with FYM, biofertilizers and zinc produced the highest grain yield. This was closely followed by the treatment receiving 75% RDF + FYM + Biofertilizer + Zn. INM (RDF + FYM + Biofertilzer + Zn) on average gave 23% higher grain yield than RDF alone showing the beneficial effect of combined use of fertilizers with FYM, Zn and biofertilizers. Similar trend was also recorded in dry matter accumulation on the basis of pooled data and biological yield during 2005-06. The increase in grain and biological yield of wheat might be due to the increased availability of essential nutrients to the crop resulting from the cumulative effect of organic sources of nutrient applied to wheat crop. Similar results have also been reported by Ba-Momen *et al.* (2007).

Nutrient uptake and balance

FIRB planting recorded significantly higher nutrient (NPK) uptake by wheat as compared to conventional planting during both the years (Table 2). This could be due to increased yields and enhanced fertilizer use efficiency in this system. The total N and K uptake by wheat

Table 2. Effect of planting system and integrated nutrient management on nitrogen, phosphorus and potassium uptake by wheat and available nutrient content in soil

Treatment	Nutrient uptake (kg/ha)						Available nutrient content in soil (kg/ha)					
	N		P		K		N		P		K	
	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06
Planting system												
Conventional	100.7	100.3	14.44	15.41	83.1	88.1	164.4	169.3	12.21	11.90	172.3	177.8
FIRB	109.3	122.6	16.04	17.62	91.1	99.7	170.7	175.9	12.65	12.26	177.0	176.3
SEm±	2.2	1.9	0.34	0.36	1.4	1.6	2.4	2.6	0.80	0.19	2.2	2.5
CD (P=0.05)	6.2	5.4	0.96	1.02	4.1	4.5	NS	NS	NS	NS	NS	NS
Nutrient management												
Control	45.6	52.3	6.13	8.41	45.7	53.1	117.9	126.8	8.01	7.95	135.2	138.4
RDF	91.6	102.2	13.71	14.96	78.0	84.7	158.5	163.3	11.04	10.99	165.5	169.2
75% RDF+FYM	102.1	110.3	15.29	16.33	83.0	89.8	163.8	169.7	11.95	11.76	168.9	171.1
75% RDF+ FYM+Zn	107.6	116.7	15.45	16.83	90.8	95.8	168.3	172.4	11.98	11.71	171.3	172.3
75% RDF+ FYM+BF	114.8	127.1	16.70	18.17	94.0	102.1	177.2	179.7	13.33	12.93	181.5	184.4
75% RDF+FYM +BF+Zn	119.7	135.2	17.26	19.12	97.9	107.3	179.8	187.9	13.91	13.51	188.4	185.6
RDF+FYM	107.3	117.8	15.59	16.31	88.4	95.3	171.1	170.1	12.19	12.01	178.8	180.3
RDF+FYM+Zn	113.3	122.7	16.55	17.45	93.5	98.9	177.7	182.3	12.05	11.93	181.4	184.5
RDF+FYM+BF	121.2	134.1	17.97	19.55	99.6	105.7	180.0	185.1	14.80	13.84	188.3	192.3
RDF+FYM+ BF+Zn	127.1	136.6	17.79	18.05	103.7	109.3	181.7	188.2	15.04	14.17	191.9	191.9
SEm±	4.8	4.1	0.75	0.79	3.4	3.5	5.3	5.8	0.40	0.43	4.5	5.6
CD (P=0.05)	13.8	11.7	2.15	2.27	9.8	10.1	15.2	16.5	1.16	1.23	14.2	16.1
Initial Status							155.5	160.4	9.71	10.11	162.1	166.3

RDF: Recommended dose of fertilizers (120-26.4-50 kg N-P-K/ha); FYM: 5 t/ha; Zn: 25 kg $ZnSO_4$/ha ; BF: Biofertilizers *viz.*, *Azotobacter chroococcum*, PSB- *Psedomonas striata* and mixed culture of VAM

Table 3. Effect of planting system and integrated nutrient management on economics (Rs/ha)

Treatment	Cost of cultivation		Net return		Benefit:cost ratio	
	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06
Planting system						
Conventional	15,807	16,240	19,659	26,404	1.23	1.61
FIRB	15,982	16,415	21,734	30,401	1.35	1.86
Nutrient management						
Control	10,674	11,036	11,678	18,520	1.09	1.68
RDF	14,498	14,900	18,895	25,787	1.30	1.73
75% RDF+FYM	15,886	16,278	19,889	27,092	1.25	1.66
75% RDF+FYM+Zn	16,476	16,990	20,801	28,372	1.26	1.67
75% RDF+FYM+BF	15,986	16,378	23,111	31,303	1.45	1.91
75% RDF+FYM+BF+Zn	16,576	17,090	23,702	32,427	1.43	1.90
RDF+FYM	16,842	17,244	20,433	28,515	1.21	1.65
RDF+FYM+Zn	17,434	17,956	21,418	28,531	1.28	1.59
RDF+FYM+BF	17,042	17,344	23,295	31,727	1.37	1.83
RDF+FYM+BF+Zn	17,532	18,056	23,748	31,748	1.35	1.76

was highest when it was supplied with RDF + FYM + BF + Zn. However, it was at par with RDF + FYM + BF and 75% RDF + FYM + BF + Zn. However during 2004-05 application of RDF + FYM + Zn in respect to N-uptake and application of 75% RDF + FYM + BF in respect to K-uptake during both the years also gave statistically similar values. N and K-uptake by wheat receiving RDF + FYM + BF + Zn was significantly higher than remaining fertility treatments. The maximum total P uptake by wheat was observed with RDF + FYM + BF during 2004-05 and 2005-06, which was significantly higher over the treatments receiving RDF, 75% RDF + FYM, 75% RDF + FYM + Zn and RDF + FYM during 2004-05 and over RDF during 2005-06 (Table 2). Remaining treatments were statistically at par with RDF + FYM + BF. The fertility treatments where NPK fertilizers were applied either in isolation or in combination with other nutrient sources resulted in significantly higher total P – uptake by wheat during both the years of experimentation. Increased N, P and K contents along with higher grain and straw yield of wheat from treatments receiving combined application of NPK fertilizers, FYM, biofertilizers and zinc resulted in higher NPK uptake by wheat as compared to the treatments where no fertilizer or manures was applied or only NPK fertilizers were applied which recorded low N, P and K contents in grains and straw on one hand and also lower grain and straw yields on the other.

Available N, P, and K in the soil after wheat harvest were not significantly influenced by planting methods, however, it improved over the initial status in the treatments where the RDF was applied either or in combination with FYM though the magnitude of increase varied across the treatments during both years of investigation (Table 2). The decrease in available NPK status of soil was recorded in control where no fertilizer was applied to the crop. Sharma *et al.* (2007) and Sharma *et al.* (2009) observed the similar findings. The beneficial effect of conjoint use of inorganic and organic sources of nutrients can be due to the release of nutrients from the organic sources through mineralization. The increased P-availability might be the result of more solubilization of native and applied P due to the combined solubilizing effect of organic acids produced on decomposition of organic manures and also because of presence of P-solubilizing microorganisms resulting in lesser P-fixation by the soils rendering it available for crop uptake.

Economics

FIRB planting system registered higher net return and benefit:cost ratio as compared to conventional planting system during both the years of study (Table 3). Highest net return was recorded in the RDF + FYM + BF + Zn however, benefit:cost ratio was found higher in 75% RDF + FYM + BF + Zn compared to remaining treatments. Sharma *et al.* (2007) also observed similar findings.

Based on the above study it is concluded that application of 90-19.8-37.5 kg N-P-K (75% RDF), 5 tonne FYM and 25 kg $ZnSO_4$/ha along with biofertilizers viz., *Azotobacter chroococcum*, PSB and mixed culture of VAM may produce higher yield, higher NPK uptake, better residual fertility and more remuneration than recommended dose of fertilizers.

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