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Improving Wheat and Soil Productivity Through Integrated Nutrient Management and Efficient Planting System

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ABSTRACT

A field experiment was conducted to developed improved wheat and soil production system through integrated nutrient management (INM) and efficient planting system (EPS)in split plot design (SPD) with 20 treatment combinations. Treatments were consist of two planting systems (conventional and FIRB) and 10 fertility treatments viz., control, RDF, 75% RDF + FYM, 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 yield contributing characters of wheat viz., number of spikes / plant and number of grains/ spike were recorded significantly higher when the crop was supplied with combined application of RDF or 75% RDF along with FYM, biofertilizer and zinc over control and treatment receiving RDF only. In case of wheat yield, 10.8 and 11.3 per cent higher yield were registered with FIRB planting system over conventional system during 2007-08 and 2008-09. However in case of integrated nutrient management, RDF + FYM + BF + Zn treatment produced 50.39 and 52.73 q/ha wheat yield respectively. The grain and straw yields increased significantly with treatment RDF + FYM + Zn over control and RDF alone. The increase in grain yield with application of RDF + FYM + BF + Zn over RDF alone was 16.8 and 14.1 per cent during 2007-08 and 2008-09, respectively. The treatment receiving fertilizer showed a higher harvest index over unfertilized control. No significant difference between planting systems was recorded in respect of available nitrogen, phosphorus, potassium and organic carbon status of soil after harvest of crop during both the years of investigation. However, a higher net positive NPK balance under FIRB planting was observed over conventional planting system. A lower bulk density in the surface soil was observed under FIRB planting system as compared to conventional planting system during both years of field study.The FIRB system of planting and combined application of RDF or 75% RDF along with FYM, biofertilizers and zinc not only gave higher productivity and profitability of wheat but also have positive effect on soil physico-chemical properties which resulted into better rhizospheroc environment.

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INTRODUCTION

Wheat is second most important cereal crop after rice of India and grown under diverse agro-climatic conditions (Jat*et al.*, 2005). Wheat is an exhaustive crop with high nutrient demand (Patel *et al.*, 1996 and Mehta, 2004).The deteriorating soil health, declining soil organic matter content and increase of micronutrient deficiencies has put a big question mark on the sustainability of wheat production (Singh *et al.*, 2012b;Tulasa and Mir 2006). Integrated nutrient management along with resource conservation technologies like FIRB planting could help in mitigating the problem to some extent. The potential sources of nutrients include chemical fertilizers, bulky organic manures and biofertilizers. Amongst these nutrient sources the chemical fertilizers play and will continue to play a vital role in meeting the crop nutrient needs (Singh and Kumar 2009; Singh *et al.*, 2012b and Sepat *et al.*, 2010).But now it has been felt that sole dependence on chemical fertilizers cannot sustain the productivity of soils in the long run. Instead the conjoint uses of macro and micronutrient fertilizers hold a great promise not only in securing high level of crop productivity but also against emergence of multiple micronutrient deficiencies (Singh and Kumar 2009 and Singh and Agarwal, 2004).Integrated nutrient management aims and improves the physical, chemical and biological health of soil and enhances the availability of both applied and native soil nutrients during growing season of the crops This helps in retarding soil degradation and deterioration of water and environmental quality by promoting carbon sequestration and checking the losses of nutrients to water bodies and atmosphere(Singh and Kumar 2009; Kaur *et al.*, 2005 and Chalwade *et al.*, 2006). Besides, organic sources of nutrient acts as slow release fertilizer as it synchronizes the nutrient demand set by plants, both in time and space, with supply of the nutrients from the labile soil and applied nutrient pools(Badiyala and Verma 1991 and Singh *et al.*, 2012b).The nutrient requirement of a crop is met by the external application of chemical or biofertilizers as soil amendment, seed/soil inoculation with biofertilizer or by foliar application (Badiyala and Verma 1991) Besides these, a part of the crop nutrient demands is also met by the available soil nutrients (Singh and Kumar 2009).The potential sources of nutrients include chemical fertilizers, bulky organic manures and

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biofertilizers (Singh and Kumar 2009; Singh *et al*., 2012b Tulasa Ram and Mir, 2006). Integrated nutrient management aims and improves the physical, chemical and biological health of soil and enhances the availability of both applied and native soil nutrients during growing season of the crops. This helps in retarding soil degradation and deterioration of water and environmental quality by promoting carbon sequestration and checking the losses of nutrients to water bodies and atmosphere (Dudhat *et al.,* 1997 and Jat *et al.,* 2006). A scientifically managed system of soil mycorrhiza bacteria plant association is useful in conserving energy by reducing fertilizer requirement of crops and meeting production targets in nutritionally deficient soils (Badiyala and Verma 1991 and Sepat *et al.,* 2010).Among agronomic practices, planting of wheat is considered to be foremost step to achieve proper distribution of plants over cultivated area, thereby better utilization of above- and below-ground resources towards yield formation (Singh *et al.,* 2012a). Recently, in several parts of the world furrow irrigated raised-bed planting system has been proved to be one of the low-cost sustainable production systems. Since variation in planting pattern modifies macro- and micro-nutrient to which plants are exposed, FIRB planting have the potential to save irrigation water, fertilizer and seed, besides significantly improving soil health (Jat *et al*., 2005 and Kumar *et al*., 2004). Such a system of nutrient management using all available sources to meet the crop needs in an integrated manner under different planting conditions will be the focal attention under proposed study (Singh *et al*., 2012b and Sepat *et al*., 2010). Keeping in view the above aspects, the present study was conducted to developed sustainable wheat production system through integrated nutrient management (INM) and efficient planting system (EPS)in split plot design (SPD) with 20 treatment combinations

MATERIALS AND METHODS

To know the effect of integrated nutrient management under different planting systems in wheat under different planting systems, present investigation was conducted at New Area Farm of NBPGR, Indian Agricultural Research Institute New Delhi-110012 during *rabi* of 2007-08 and 2008-09. The experiment was consist of 20 treatment combinations and were tested a split plot design and replicated thrice. The topography of field was fairly uniform with a gentle slope. A composite soil sample was collected from the experimental field to study the contents of available N, P and K, pH, electric conductivity organic carbon content and some physical properties of the soil. The soil analysis revealed that the soil was sandy-loam in texture, low in organic carbon, available nitrogen and available phosphorus contents while it was medium in available potassium. The soil reaction was near neutrality with slight alkaline tendency. The tested wheat variety was WR 544 (Pusa Gold) a late sown bread wheat variety released by IARI New Delhi in 2005 and recommended for irrigated conditions of Delhi region.

A pre-sowing irrigation was given to the experimental field for land preparation. The field was then levelled properly and the experiment was laid out such that the treatment blocks in each replication were arranged across the slope. After laying out the experiment, FYM @ 5 t ha^{-1} was applied 12-15 days before sowing as per the treatments. Wheat received 67.5 kg N ha^{-1} as basal dose of nitrogen in the form of urea at the time of sowing and the remaining 67.5 kg N ha^{-1} was applied after first irrigation. 60 kg P_2O_5 ha^{-1} as SSP, 60 kg K_2O ha^{-1} as muriate of potash and 25 kg $ZnSO_4$ ha^{-1} were applied with *pora* at the time of sowing. The wheat seed used for sowing the plots receiving biofertilizer treatment was inoculated with *Azotobacter* and PSB cultures obtained from the Division of Microbiology, IARI, New Delhi. For inoculation 10 per cent *gur* slurry was prepared by boiling the *gur* solution. The cultures of *Azotobacter* and PSB were then mixed in the cooled *gur* slurry. This mixture was then poured on the wheat seed which was uniformly spread on the polythene sheet. The slurry was then thoroughly mixed to coat each wheat seed with it. The inoculated seed was dried in shade and subsequently used for sowing.Seed was sown in rows spaced 22.5 cm apart by *kera* method using seed rate of 125 kg ha^{-1}. Sowing under conventional method was done by seed drill. FIRB planting of wheat was done through tractor drawn FIRB planter which made beds along with sowing. The width of bed and furrow was around and 30 cm, respectively. Three rows of wheat were sown in single bed. Two manual weeding were done at 30 and 60 DAS. The crop received five irrigations during the crop season the schedules for the same. Wheat being a *rabi* season crop does not face any serious pest problem so was not sprayed with any insecticide.

Data was recorded on grain and straw yield, Nutrient content and uptake in grains and straw. Soil physical and chemical properties were also recorded to assess the dynamics of soil fertility status to gauge the productivity. Standard techniques were adopted to record the data. For the recording of plant height, five plants were tagged in each plot and were used for recording of plant height at various crop growth stages upto harvest. Grain yield of each net plot was recorded for wheat crop after threshing and expressed in q/ha. For straw yield calculation grain yield per plot was deducted from the biological yield per plot to get the straw yield in wheat. The straw yield was expressed in q/ha. Similarly harvest index was worked out for wheat crop from their respective economic (grain) yield and biological yields as per the formula (Eq.1) given by Nichiporovich (1995).

$$\text{HI (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100 \qquad \text{[Eq.1]}$$

The plants chosen for recording growth and yield attributes were used for determination of N, P and K contents. The plant samples (grain and straw) were oven dried and ground to fine powder to pass through 40 mesh sieve and were used for analysis. The plant N content (%) was determined by modified Kjeldahl's method (Piper, 1966). The total P content in plants was estimated by Vanadomolybdo phosphoric yellow colour method (Jackson, 1973). The K content in plants was estimated by Flame Photometer method (Jackson, 1973). The N, P and K contents in the plant samples were multiplied with the respective grain and straw yields and added to get the NPK uptake and was presented as kg ha^{-1}. Protein content of grain was determined by multiplying the N content of grains by a factor of 5.73.

Soil samples were collected from the plough layer at the beginning of the experiment and after harvesting each crop. These samples were air dried, ground, sieved and then used in chemical analysis for determination of soil organic-C content, available N, P and K content of the soil. Organic-C content in the soil was determined by the wet combustion method commonly known as Walkley Black method given by Walkley and Black in 1934. Available N content of soil samples was estimated by Alkaline Permanganate Method given by Subbiah and Asija (1956) and presented as kg N ha^{-1}. Available P content of the soil samples was estimated by the Olsen method (Olsen *et al*., 1954). Available K content was determined by the 1N Ammonium acetate solution method given by Merwin and Peech (1951). The soil bulk density was measured by the core method given by Black and Hartge (1986) in which the core sampler was pressed vertically into the soil to fill the soil samples. After this the sampler along with its content was removed and the soil extending beyond each end of the sample holder was trimmed so that the soil sample volume becomes equal to the volume of the soil sample holder. Then the soil was transferred to a metallic container, kept in oven at 105°C until it reached a constant weight. It was weighed and the bulk density was calculated by dividing the oven dry mass of the soil sample with the sample volume and presented as Mg m^{-3}. Data generated during the course of experimentation were statistically analysed by using the Analysis of Variance (ANOVA) technique as detailed by Cochran and Cox (1967).

RESULTS AND DISCUSSIONS

Wheat grain and straw yield (q/ha)

The data related to grain yield (q/ha) of wheat as observed during 2007-08 and 2008-09 were presented in Table 1. Results revealed that there is significant difference in grain yield among different planting systems. During 2007-08, FIRB planting system recorded grain yield of 45.59 q/ha which was significantly higher as compared to conventional planting system (41.15 q/ha). The percentage increase in grain yield of wheat in FIRB planting system was 10.8 over conventional system. During 2008-09, a grain yield of 48.73 q/ha was observed under FIRB planting system. It was significantly higher as compared to conventional system which recorded a grain yield of 43.80 q/ ha. The FIRB system registered an 11.3 per cent combination with organic manures was observed over the unfertilized control during both the years of study. FIRB planting system gave significantly higher straw yield (59.94 and 62.18 q/ha) over conventional planting system during both the years of study. Application of fertilizer registered significantly higher straw yield over control during 2007-08 and 2008-09. The highest straw yield of 69.49 and 71.22 q/ha was observed with application of RDF + FYM + BF + Zn during years 2007-08 and 2008-09, respectively. During 2007-08, the treatment receiving RDF + FYM + BF + Zn observed significantly higher straw yield over the treatments RDF only and 75% RDF + FYM while during 2008-09, it

Table 1: Effect of planting system and integrated nutrient management on yield of wheat

Treatments	Grain yield (q/ha)		Straw yield (q/ha)		Harvest index (%)	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
Planting systems						
Conventional	41.15	43.80	57.48	58.20	41.68	42.90
FIRB	45.59	48.73	59.94	62.18	43.16	43.96
SEm±	0.668	0.548	0.800	0.546	0.284	0.289
LSD (P=0.05)	1.914	1.569	2.291	1.563	0.814	0.828
Nutrient management						
Control	29.43	31.72	43.09	44.66	40.55	41.43
135 kg N + 60 kg P2O5 + 60 kg K2O/ha (RDF)	43.15	46.21	57.74	59.93	42.75	43.50
75% RDF + FYM	39.09	41.54	51.54	53.35	43.10	43.72
75% RDF + FYM + Zn	40.72	45.29	54.38	56.18	42.79	44.61
75% RDF + FYM + BF	42.41	45.77	56.25	57.73	42.96	44.19
75% RDF + FYM + Zn + BF	45.94	49.33	60.79	62.56	43.02	44.05
RDF + FYM	45.36	48.22	61.53	59.07	42.41	45.06
RDF + FYM + Zn	47.92	51.22	65.59	68.00	42.20	42.94
RDF + FYM + BF	49.28	50.65	66.74	69.24	42.45	42.24
RDF + FYM + Zn + BF	50.39	52.73	69.49	71.22	42.02	42.54
SEm±	1.495	1.225	1.789	1.220	0.636	0.647
LSD (P=0.05)	4.280	3.509	5.123	3.494	N.S.	1.852

recorded significantly higher straw yield over treatments RDF only, 75% RDF + FYM + BF and RDF + FYM +Zn (Mehta 2004, Singh and Agarwal 2004).

Among different nutrient management treatments, the treatment where recommended dose of fertilizers (RDF) were applied in combination with FYM, biofertilizers and zinc produced the highest grain yield of 50.39 and 52.73 q/ha during 2007-08 and 2008-09, respectively. The treatment was followed by the treatment receiving RDF + FYM + BF during 2007-08 which recorded grain yield of 49.28 q/ha and application of RDF + FYM + Zn during 2008-09 i.e. 51.22 q/ha. During both the years of study, the treatments RDF + FYM + Zn and RDF + FYM + BF were statistically at par with RDF + FYM + BF + Zn while the treatments receiving 75% RDF + FYM + Zn + BF also produced significantly on par grain yield during 2008-09 to the RDF + FYM + BF + Zn (Mehta, 2004 and Sepat *et al*., 2010).The highest yielding treatment receiving combined application of RDF + FYM + BF + Zn gave 16.78 and 14.11 per cent higher grain yield than RDF alone during the years 2007-08 and 2008-09, respectively showing the beneficial effect of combined use of NPK fertilizers along with FYM and biofertilizers higher grain yield over conventional system. The application of nutrients either through chemical fertilizers alone or in combination with FYM, biofertilizers and Zn had a significant effect on the grain yield of wheat crop during both the years of study (Kumar *et al*., 2004; Sepat *et al*., 2010 and Tulasa and Mir 2006).

The grain and straw yield of wheat vary significantly due to planting systems (Table 1). Grain and straw yields were significantly higher under FIRB planting system. The FIRB planting system registered a 10.8 and 11.3 per cent higher grain yield over conventional system during 2007-08 and 2008-09, respectively. The increase in grain yield could be attributed to higher number of growth, root and yield contributing characters under FIRB planting of wheat. Whereas, the increase in straw yield was may due to higher dry matter accumulation under bed planting of wheat. Higher grain and straw yield recorded in FIRB planting can also be attributed to better soil environment in ridges since prolonged pounding reduces yield as observed under conventional planting system. The formation of double fertile layer of the soil is also responsible for higher yield under FIRB system as the top 10 cm fertile soil also transfer to the crop root zone over beds (Sepat *et al*., 2010; Singh and Agarwal 2004). The increase in grain and straw 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. The harvest index of wheat also recorded a trend similar to grain yield but the treatment differences were short of significance. The application of RDF + FYM + BF + Zn resulted into 16.78 and 14.11 2007-08 and 2008-09 respectively (Singh and Agarwal 2004 and Tulasa and Mir 2006).

Harvest index represents the proportion of total dry matter of crop partitioned towards the grains that forms the economic yield. Data regarding harvest index of wheat (Table 1) showed

Table 2: Effect of planting system and integrated nutrient management on N concentration and uptake of wheat

Treatments	N concentration in grain (%)		N concentration in straw (%)		N uptake by grain (kg/ha)		N uptake by straw (kg/ha)		Total N uptake (kg/ha)	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
Planting systems										
Conventional	1.64	1.66	0.499	0.502	68.11	73.35	29.07	29.60	97.18	102.95
FIRB	1.65	1.66	0.503	0.505	76.07	81.46	30.54	31.78	106.61	113.24
SEm±	0.014	0.012	0.005	0.005	0.600	0.763	0.277	0.212	0.961	0.852
LSD (P=0.05)	N.S.	N.S.	N.S.	N.S.	1.717	2.185	0.794	0.606	2.751	2.439
Nutrient management										
Control	1.26	1.28	0.304	0.308	37.10	40.60	13.11	13.77	50.20	54.37
135 kg N + 60 kg P_2O_5 + 60 kg K_2O/ha (RDF)	1.65	1.66	0.515	0.519	70.99	76.49	29.74	31.08	100.73	107.57
75% RDF + FYM	1.59	1.60	0.510	0.512	62.17	66.50	26.26	27.32	88.43	93.82
75% RDF + FYM + Zn	1.63	1.66	0.514	0.515	66.18	75.10	27.93	28.93	94.11	104.03
75% RDF + FYM + BF	1.65	1.66	0.515	0.517	69.78	75.76	28.97	29.85	98.74	105.61
75% RDF + FYM + Zn + BF	1.67	1.68	0.521	0.523	76.49	82.63	31.67	32.69	108.16	115.32
RDF + FYM	1.72	1.72	0.524	0.526	77.79	82.94	32.24	31.08	110.03	114.02
RDF + FYM + Zn	1.73	1.74	0.532	0.534	82.91	89.15	34.89	36.28	117.81	125.42
RDF + FYM + BF	1.75	1.76	0.533	0.537	86.00	88.90	35.57	37.18	121.57	126.08
RDF + FYM + Zn + BF	1.82	1.82	0.542	0.544	91.48	95.96	37.66	38.74	129.14	134.70
SEm±	0.031	0.026	0.011	0.011	1.341	1.706	0.620	0.473	2.148	1.904
LSD (P=0.05)	0.090	0.074	0.030	0.030	3.840	4.885	1.776	1.356	6.150	5.454

significant difference between the planting systems during both the years and it was higher in FIRB. Among nutrient management, all the treatments recorded statistically at par harvest index during 2007-08 but significantly superior in all treatment over control in 2008-09. The numerically highest harvest index of 43.1 was observed with 75% RDF + FYM during 2007-08, while it was 45.06 during 2008-09 with 75% RDF + FYM + Zn + BF. The lowest harvest index (40.55 and 41.43) was recorded in treatment where no fertilizer or manure was applied (Singh and Agarwal 2004 and Tulasa and Mir 2006).

Nutrient Content

The data pertaining to nitrogen concentration in grain and straw of wheat during 2007-08 and 2008-09 are presented in Table 2. Results indicated that a higher N- concentration in grains and straw was observed with FIRB system of planting which was statistically at par with conventional planting system during both years of experimentation. The nitrogen, phosphorus, potassium content in grain and straw of wheat were not influenced significantly by planting systems. However, FIRB planting system improved the nitrogen, phosphorus and potassium uptake significantly as compared to that of conventional planting system. This could be due to increased yields and enhanced fertilizer use efficiency in this system over the conventional planting system. As the uptake is product of concentration and yield hence it enhanced the uptake of NPK by wheat due to more yield under FIRB (Patel *et al.*, 1996; Badiyala and Verma1991 and Jat *et al.*, 2005). The adequate supply of plant nutrients resulting from their application through inorganic and organic sources resulted in higher N, P and K contents in grains and straw of wheat during both the years of study.

A significant and positive impact of fertilizer application on N concentration in grain and straw of wheat was recorded as compared with control during the two years of investigation. During both the years, the treatment RDF + FYM + BF + Zn recorded highest N concentration of 1.78 per cent in grains of wheat which was significantly higher over treatment receiving RDF only. In straw, the treatment RDF + FYM + BF + Zn recorded significantly higher N- concentration during both years of study. It was significantly higher over treatment receiving RDF only.The N-content in wheat grains and straw increased significantly in treatments receiving NPK fertilizers either alone or in combination with organic sources over the unfertilized control and the highest N-content in both grain and straw was recorded in treatment receiving RDF + FYM + BF + zinc during both the years (Duthat *et al.*, 1997; Patel *et al.*, 1996 and Singh and Agarwal 2004).

A perusal of data in Table 3 reveals the effect of different treatments on phosphorus concentration (%) in grain and straw of wheat during 2007-08 and 2008-09. During both the years of study, FIRB planting system recorded higher P-concentration in grain and straw of wheat which was statistically at par as compared to conventional system of planting. The application of NPK fertilizers either alone or in

Table 3: Effect of planting system and integrated nutrient management on P concentration and uptake of wheat

Treatments	P concentration in grain (%)		P concentration in straw (%)		P uptake by grain (kg/ha)		P uptake by straw (kg/ha)		Total P uptake (kg/ha)	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
Planting systems										
Conventional	0.296	0.298	0.0332	0.0335	12.37	13.26	1.91	1.95	14.28	15.21
FIRB	0.302	0.304	0.0354	0.0356	13.92	14.97	2.12	2.22	16.05	17.19
SEm±	0.003	0.005	0.0004	0.0005	0.11	0.10	0.01	0.01	0.10	0.15
LSD (P=0.05)	N.S.	N.S.	N.S.	N.S.	0.33	0.29	0.03	0.05	0.29	0.43
Nutrient management										
Control	0.202	0.205	0.0326	0.0330	5.93	6.49	1.40	1.47	7.34	7.97
135 kg N + 60 kg P_2O_5 + 60 kg K_2O/ha (RDF)	0.297	0.300	0.0349	0.0351	12.80	13.85	2.01	2.10	14.81	15.95
75% RDF + FYM	0.288	0.291	0.0330	0.0333	11.24	12.10	1.70	1.78	12.94	13.88
75% RDF + FYM + Zn	0.307	0.308	0.0335	0.0337	12.48	13.93	1.82	1.89	14.30	15.82
75% RDF + FYM + BF	0.308	0.311	0.0341	0.0343	13.07	14.21	1.91	1.98	14.98	16.20
75% RDF + FYM + Zn + BF	0.313	0.315	0.0338	0.0339	14.36	15.54	2.05	2.12	16.41	17.66
RDF + FYM	0.315	0.316	0.0347	0.0348	14.26	15.24	2.13	2.06	16.40	17.30
RDF + FYM + Zn	0.318	0.320	0.0353	0.0357	15.24	16.37	2.31	2.42	17.55	18.79
RDF + FYM + BF	0.321	0.322	0.0353	0.0359	15.79	16.31	2.35	2.48	18.15	18.79
RDF + FYM + Zn + BF	0.323	0.325	0.0363	0.0361	16.27	17.11	2.52	2.57	18.79	19.68
SEm±	0.007	0.010	0.0009	0.0010	0.25	0.22	0.02	0.04	0.23	0.34
LSD (P=0.05)	0.019	0.029	N.S.	N.S.	0.74	0.64	0.08	0.11	0.66	0.98

combination with organic sources of nutrients significantly increased the P- concentration in the grain and straw of wheat over the control. The highest grain and straw P- concentration was recorded in the treatment receiving RDF + FYM + BF during the years 2007-08 and 2008-09. During 2007-08 grain P-concentration with application of RDF + FYM + BF (0.323 per cent) was significantly higher over treatment receiving RDF only. The same trend was also observed in 2008-09. Wheat on straw P- concentration found to be non significant between the different treatments but control recorded lowest straw P-concentration during both years of study (Badiyala and Verma1991).

Data presented in Table 4 regarding K-concentration of grain and straw of wheat during 2007-08 and 2008-09. Perusal of data revealed that no significant difference in K-concentration of grain and straw was observed between FIRB and conventional planting system during both years of study. However, a higher K- concentration in grain and straw was observed in FIRB planting. A significant increase in K-concentration in grain and straw of wheat was registered upon the application of NPK fertilizers as compared to control during the two years of study. But the different fertility treatments recorded statistically similar straw K-concentration as the differences between them did not reach to a level of significance (Duthat *et al.*, 1997; Patel *et al.*, 1996 and Singh and Agarwal, 2004).

Nutrient uptake

The data pertaining to nitrogen uptake by grain and straw and total by wheat during 2007-08 and 2008-09 presented in Table 2. FIRB system of planting recorded significantly higher nitrogen uptake in wheat grain as compared to conventional system of planting. The nitrogen uptake by wheat straw was also observed higher with FIRB planting system. The trend observed in total nitrogen uptake during both years of study was similar as recorded in nitrogen uptake by wheat grain and straw. A perusal of data also revealed a significant increase in N-uptake by grain and straw as well as total N-uptake by wheat when it was supplied with adequate amounts of NPK fertilizers either alone or in combination with FYM, biofertilizers or zinc over the unfertilized control during both the years of experimentation. Amongst the different fertility treatments, the treatment receiving RDF + FYM + BF + Zn recorded significantly highest N uptake of 91.48 and 95.96 kg/ha by wheat grain during 2007-08 and 2008-09, respectively. All the fertilization treatments recorded higher N uptake by wheat grain compared to control. Maximum N-uptake by wheat straw was observed with application of RDF + FYM + BF + Zn which was significantly highest over other treatments during both the year of study. The total N-uptake by wheat was significantly highest (129.14 and 134.70 kg/ha during 2007-08 and 2008-09, respectively) when it was supplied with RDF + FYM + BF + Zn. The nutrient applied treatment recorded higher N- uptake compared to control during both the years of study(Badiyala and Verma1991; Duthat *et al.*, 1997and Patel *et al.*, 1996).

Table 4: Effect of planting system and integrated nutrient management on K concentration and uptake of wheat

Treatments	K concentration in grain (%)		K concentration in straw (%)		K uptake by grain (kg/ha)		K uptake by straw (kg/ha)		Total K uptake (kg/ha)	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
Planting systems										
Conventional	0.327	0.329	1.20	1.21	13.51	14.47	69.31	70.70	82.82	85.16
FIRB	0.333	0.335	1.22	1.24	15.26	16.37	73.52	77.10	88.78	93.47
SEm±	0.003	0.004	0.012	0.011	0.152	0.128	0.698	0.677	0.585	0.830
LSD (P=0.05)	N.S.	N.S.	N.S.	N.S.	0.436	0.365	1.999	1.939	1.676	2.377
Nutrient management										
Control	0.300	0.303	1.14	1.16	8.82	9.60	49.13	51.59	57.95	61.19
135 kg N + 60 kg P_2O_5 + 60 kg K_2O/ha (RDF)	0.326	0.327	1.21	1.22	14.05	15.12	69.87	73.12	83.92	88.24
75% RDF + FYM	0.324	0.326	1.19	1.20	12.67	13.54	61.35	63.78	74.02	77.32
75% RDF + FYM + Zn	0.327	0.328	1.21	1.22	13.30	14.86	65.55	68.28	78.86	83.14
75% RDF + FYM + BF	0.327	0.329	1.21	1.22	13.88	15.07	68.07	70.14	81.94	85.21
75% RDF + FYM + Zn + BF	0.338	0.341	1.23	1.23	15.53	16.82	74.46	76.95	90.00	93.77
RDF + FYM	0.332	0.334	1.22	1.24	15.07	16.12	75.07	73.04	90.15	89.16
RDF + FYM + Zn	0.340	0.341	1.23	1.25	16.30	17.48	80.68	84.68	96.98	102.16
RDF + FYM + BF	0.343	0.344	1.25	1.26	16.88	17.40	83.11	86.91	99.99	104.32
RDF + FYM + Zn + BF	0.344	0.345	1.25	1.27	17.34	18.16	86.87	90.47	104.20	108.64
SEm±	0.007	0.008	0.026	0.025	0.341	0.285	1.561	1.514	1.309	1.856
LSD (P=0.05)	0.019	0.023	N.S.	N.S.	0.975	0.816	4.469	4.336	3.747	5.315

Data related to P-uptake by whet was presented in Table 3. P-uptake by wheat crop was significantly influenced by the different planting systems. FIRB planting system recorded significantly higher P-uptake by wheat grain and straw as well as total P-uptake during the years 2007-08 and 2008-09. The fertility treatments where NPK fertilizers were applied either sole or in combination with other nutrient sources resulted in significantly higher P-uptake by wheat grain and straw as well as total P-uptake during both years of experimentation. The maximum P-uptake of 16.28 and 17.11 kg/ha during 2007-08 and 2008-09, respectively, by wheat grain was observed with application of RDF + FYM + BF + Zn which was significantly higher over other treatments. Similar trend was observed in P-uptake by straw as well as total P-uptake during both years of study. However total P-uptake was on par with RDF + FYM + BF application (Badiyala and Verma1991; Duthat *et al.,* 1997and Patel *et al.,* 1996).The grain P-content increased significantly over control upon application of fertilizers, manures and biofertilizers but the differences between fertilizer receiving treatments remained non-significant. The highest P-content in treatment receiving RDF + FYM + BF can be explained on the basis of higher P-input through FYM and increased solubilization by PSB's and mobilization by the mycorrhizae.

The Table 4 enumerated the results related to the K-uptake by wheat during 2007-08 and 2008-09. FIRB system of planting observed significantly higher K-uptake by wheat grain (15.26 and 16.37 kg/ha during 2007-08 and 2008-09, respectively) as compared to conventional system of planting. Similar trend was registered by wheat straw as well as total K-uptake by wheat during both the years of investigation. The fertility treatments where NPK fertilizers were applied either in isolation or in combination with other nutrient sources resulted in significantly higher K-uptake by wheat crop over the control. The significantly highest K-uptake of 17.34 and 18.16 kg/ha by wheat grain was observed with treatment receiving RDF + FYM + BF + Zn during both years of investigation. Similar trend was recorded in K-uptake by wheat straw and total K-uptake by wheat during the years 2007-08 and 2008-09. This treatment was on par with RDF + FYM + Zn and RDF + FYM + BF in terms of K-uptake by wheat grain straw as well as total (Badiyala and Verma1991 and Duthat *et al.,* 1997). Increased nitrogen, phosphorus and potassium 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 uptake of nitrogen, phosphorus and potassium by wheat crop 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 (Duthat *et al.,* 1997and Patel *et al.,* 1996).

Soil physico-chemical properties

Data depicted in The Table 5 enumerated the results related to the organic carbon in soil during both years of investigation. The difference observed in soil organic carbon content under FIRB and conventional planting system did not reach up to significance level during both the years of experimentation.

Table 5: Effect of planting system and integrated nutrient management on organic carbon (%)

Treatments	2007 -08	2008 -09
Planting systems		
Conventional	0.35	0.37
FIRB	0.36	0.39
SEm±	0.01	0.01
LSD (P=0.05)	NS	NS
Nutrient management		
Control	0.34	0.36
135 kg N + 60 kg P_2O_5 + 60 kg K_2O/ha (RDF)	0.35	0.37
75% RDF + FYM	0.35	0.38
75% RDF + FYM + Zn	0.35	0.38
75% RDF + FYM + BF	0.35	0.39
75% RDF + FYM + Zn + BF	0.35	0.39
RDF + FYM	0.35	0.38
RDF + FYM + Zn	0.35	0.38
RDF + FYM + BF	0.36	0.39
RDF + FYM + Zn + BF	0.36	0.39
SEm±	0.01	0.01
LSD (P=0.05)	NS	NS

The soil organic carbon content (%) showed an increasing trend with the integration of inorganic fertilizers with the organic sources of nutrient during both the years of study, however, the treatment differences did not reach up to a level of significance. Further, perusal of data furnished in Table 6 reveals the effect of different treatments on bulk density of soil. FIRB system of planting recorded a significantly lower bulk density of 1.47 and 1.46 Mg/m^3 of soil as compared to conventional planting system during the years 2007-08 and 2008-09. The application of nutrient through organic sources like FYM registered a slightly lower bulk density of the soil as compared to inorganic fertilizer alone or the control (Badiyala and Verma1991 and Chalwade *et al.*, 2006 Kaur *et al.*, 2005). Among the different fertility treatments, the treatments where NPK fertilizers were applied in conjunction with FYM, biofertilizers and zinc registered numerically higher values though the difference between all the treatments were non-significant. The maximum soil organic carbon content of 0.36 and 0.39% during 2007-08 and 2008-09, respectively, was recorded with treatment receiving RDF + FYM + BF + Zn and RDF + FYM + BF. The treatment differences, however, lacked significance and all the treatments were statistically at par. The combined application of FYM with chemical fertilizers tends to lower the soil bulk density through their favorable impact on soil granulation and increased porosity in the soils but again the treatment difference lacked significance because of relatively stable nature of these important soil physical properties (Chalwade *et al.*, 2006 and Mehta, 2004).

Table 6: Effect of planting system and integrated nutrient management in wheat on bulk density of soil (Mg/m^3)

Treatments	2007-08	2008-09
Planting systems		
Conventional	1.55	1.56
FIRB	1.47	1.48
SEm±	0.01	0.01
LSD (P=0.05)	0.02	0.02
Nutrient management		
Control	1.53	1.54
135 kg N + 60 kg P_2O_5 + 60 kg K_2O/ha (RDF)	1.53	1.54
75% RDF + FYM	1.51	1.52
75% RDF + FYM + Zn	1.51	1.52
75% RDF + FYM + BF	1.5	1.51
75% RDF + FYM + Zn + BF	1.52	1.53
RDF + FYM	1.51	1.52
RDF + FYM + Zn	1.49	1.5
RDF + FYM + BF	1.5	1.51
RDF + FYM + Zn + BF	1.51	1.52
SEm±	0.05	0.05
LSD (P=0.05)	NS	NS

Perusal of data pertaining to available nitrogen (Table 7) revealed that higher available nitrogen in soil was observed under FIRB planting system which was at par with conventional planting system. Among nutrient management treatments, a significant impact of different treatments was observed on the available nitrogen status of soil at the end of each crop. The available nitrogen content of the soil decreased appreciably in the control plot. The treatment receiving RDF + FYM + BF + Zn registered the highest (183.7 and 190.2 kg N/ ha) during 2007-08 and 2008-09 respectively available N-status of the soil at the end of wheat crop during both the years of study. This treatment recorded significantly higher available N-status of soil over treatments RDF, 75% RDF + FYM and 75% RDF + FYM + Zn was at par with remaining fertilizer receiving treatments during both the years of study. The data related to available phosphorus in soil was presented in Table 7. Among planting system, no significant difference was observed in available P-status of soil during both years of investigation. The available P-status of the soil at the end of wheat crop improved over the initial status in the treatments where the recommended rate of NPK fertilizers was applied either in isolation or in combination with other sources of nutrients though the magnitude of increase varied across the treatments during both years of investigation. The decrease in available P-status of soil was recorded in control where no fertilizer was applied to the crops. The treatment receiving combined application of NPK fertilizer, FYM, biofertilizers and zinc recorded highest (15.5 and 14.7 kg P/ ha) during 2007-08 and 2008-09 respectively available P-content of the soil at the end of wheat crop during both the years of study. The treatments receiving RDF + FYM + BF recorded at par available P- in the soil as compared to treatment recording highest available P-status (Kaur *et al.*, 2005 and Singh and Agrawal 2004).

The data pertaining to available K-status of soil at the end of wheat crop during the years 2007-08 and 2008-09 are presented in Table 4. Both the planting systems showed a statistically at par available K-status of soil at the end of what crop during both the years of experimentation. The treatments receiving RDF + FYM + BF +Zn registered the highest available K-content in soil (193.9 kg K/ ha) which was significantly higher than the treatments where only RDF, 75% RDF + FYM and 75% RDF + FYM + Zn were applied. All the remaining treatments were at par during both years of experimentation except control which recorded lowest available K-content in soil at the end of wheat crop (Chalwade *et al.*, 2006 and Kaur *et al.*, 2005).

Available nitrogen, phosphorus, potassium and organic carbon in the soil were not significantly influenced by planting methods after harvest of the wheat. In FIRB planting method in spite of higher yield and nutrient uptake no decrease in nutrient availability and organic carbon of soil was recorded. This was mainly owing to the fact that in FIRB

Table 7: **Effect of planting system and integrated nutrient management on available N, P and K in the soil after harvest of wheat (kg/ha)**

Treatments	Available N		Available P		Available K	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
Planting systems						
Conventional	166.0	170.9	12.6	12.3	173.9	179.4
FIRB	172.3	177.5	13.0	12.7	178.6	177.9
SEm±	4.9	3.0	0.3	0.3	7.3	6.8
LSD (P=0.05)	NS	NS	NS	NS	NS	NS
Nutrient management						
Control	115.9	124.8	7.5	7.5	133.2	136.4
135 kg N + 60 kg P_2O_5 + 60 kg K_2O/ha (RDF)	160.5	165.3	11.5	11.5	167.5	171.2
75% RDF + FYM	165.8	171.7	12.5	12.3	170.9	173.1
75% RDF + FYM + Zn	170.3	174.4	12.5	12.2	173.3	174.3
75% RDF + FYM + BF	179.2	181.7	13.8	13.4	183.5	186.4
75% RDF + FYM + Zn + BF	181.8	189.9	14.4	14.0	185.4	187.6
RDF + FYM	173.1	172.1	12.7	12.5	180.8	182.3
RDF + FYM + Zn	179.7	184.3	12.6	12.4	183.4	186.5
RDF + FYM + BF	182.0	187.1	15.3	14.3	190.3	194.3
RDF + FYM + Zn + BF	183.7	190.2	15.5	14.7	193.9	193.9
SEm±	4.3	4.8	0.3	0.4	3.7	4.4
LSD (P=0.05)	12.3	13.7	0.9	1.0	10.7	12.6

planting system nutrients applied at sowing were concentrated in beds while their formation and second dose of nitrogen in this method was applied on beds. Thus, in this method plants might have absorbed and utilized nutrients more efficiently than conventional method of planting where nutrients were spread throughout the soil mass. This is also the reason for higher net positive NPK balance under FIRB planting as compared to conventional planting system. The formation of double fertile layer of the soil is also responsible for this. A lower bulk density in the surface soil was observed under FIRB planting than conventional planting system (Table 6). This happened because the top of bed remains loose as a result of tilling of soil. The lower bulk density means more porosity which resulted in to higher moisture retention under FIRB planting over conventional planting system(Chalwade *et al.*, 2006 and Kaur *et al.*, 2005).

The supply of nutrients for the plant growth in an integrated form by combining inorganic fertilizers with organic manures had a positive impact on the soil properties. The combined application of RDF or 75% RDF along with FYM, biofertilizers and zinc registered the highest soil organic carbon, though the differences between treatments remained short of significance. This is because of the addition of 5 tonnes/ha of FYM tends to increase the organic carbon content of the soil over the control and also over the treatments where only recommended dose of NPK fertilizers (RDF) were applied but it lacked significance over the control because soil organic carbon content being a relatively stable soil property required long term applications of organic manures for its maintenance or enhancement. The beneficial effect of conjoint use of inorganic and organic sources of nutrients was also evident in the available nutrient status of the soil at the completion of each crop cycle. Where the treatment receiving combined application of 75% RDF or RDF along with FYM, biofertilizers and zinc resulted in significantly higher available nitrogen phosphorus and potassium content in the soil as compared to control and the treatments where only recommended rates of NPK fertilizers (RDF) were applied which 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 solubilizying 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. The integration of inorganic and organic sources of nutrients had a positive effect on soil nutrient balances. The combined application of RDF or 75% RDF along with FYM, biofertilizers and zinc resulted in higher positive soil nitrogen balance over control which recorded a net negative N-balance in soil. This might have resulted from the addition of nitrogen in higher amounts upon combined application of NPK fertilizers and FYM. In case of phosphorus, a net positive balance was observed in all the treatments except control which recorded a net negative balance at the end of wheat crop. Further, the build up of soil phosphorus was highest in treatments where the sources of nutrients were integrated at the highest level. The integration of NPK fertilizers, FYM and biofertilizers also resulted in a high net positive balance of potassium as compared with the control. It can be explained on the basis of high amounts of K-addition coming from both organic and inorganic sources (Chalwade *et al.*, 2006 and Kaur *et al.*, 2005 and Badiyala and Verma1991).

CONCLUSION:

The FIRB system of planting and combined application of RDF or 75% RDF along with FYM, biofertilizers and zinc not only gave higher productivity and profitability of wheat but also have positive effect on soil physico-chemical properties which resulted into better rhizospheroc environment.

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