Indian Journal of Agricultural Sciences **83** (6): 627–32, June 2013/Article

Effects of nutrient management and planting systems on root phenology and grain yield of wheat (*Triticum aestivum*)

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Received: 16 January 2013; Revised accepted: 21 February 2013

ABSTRACT

A field experiment was conducted in split plot design (SPD) with 20 treatment combinations for two years (2007-08 and 2008-09) at NBPGR, New Area Farm, IARI, New Delhi during *rabi* seasons. 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. Results revealed that the root dry weight, root volume, root length and root length density were recorded higher values in FIRB planting system than conventional system at all growth stages during both the years of investigation. Whereas in case of integrated nutrient management, root growth parameters of wheat, viz. root dry weight, root volume, root length and root length density were significantly higher at various observational growth stages when crop was supplied with combined application of RDF or 75% RDF along with FYM, biofertilizer and zinc over the control and treatment RDF only during both years of field study. However, specific root length was significantly lower under treatment receiving RDF or 75% RDF + FYM + BF + Zn as compared to control at 30 and 60 DAS during the years, 2007-08 and 2008-09. In case of wheat yield, 10.8 and 11.3% 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.

Key words: Economics, FIRB, Nutrient management, Root development, Wheat

India's post-independence progress in foodgrains production has slightly been described as the transformation from begging bowl to the bread basket (Swaminathan 1996). Wheat crop is a very important and remunerative crop in North India. It is the second most important cereal crop after rice, grown under diverse agro-climatic conditions and occupied an area of 28.52 m ha with the annual production of 80.71 m tonnes with an average yield of 2.83 tonnes/ha during 2009-10 (Anonymous 2010). Economically, wheat is becoming less and less profitable because of increasing input costs. Roots not only act as a sink for mineral nutrients transported to the root surface by mass flow and diffusion but also they take up either ions or water preferentially which may lead to the depletion or accumulation of ions (Kaur *et al.* 2005 and Mehta 2004). Root exudates may mobilize mineral nutrients directly and primarily provides the energy for microbial activity in the rhizosphere (Aggarwal *et al.* 2006).These root induced modifications are of crucial importance for mineral nutrition of plants and thus, the conditions of the rhizosphere and the extent to which the roots can modify them are decisive for nutrient uptake (Aggarwal *et al.* 2006 and Weaver 1926). Better understanding of root system structure and function is critical to crop improvement in water-limited environments. The aims of this study were to examine root system characteristics of wheat genotype under nutrient management and planting systems. Root development and distribution in soils are important information for root–water and nutrient-uptake studies in soil–plant systems (Ahmad *et al*. 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 (Ba Bomen *et al.* 2007, Jat *et al.* 2006 and 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 (Dudh at *et al.* 1997 and Jat *et al.*

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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 (Sepat *et al.* 2010).

MATERIALS AND METHODS

The field experimental work of the investigation was conducted during *rabi* of 2007-08 and 2008-09 at NBPGR, New Area Farm, Indian Agricultural Research Institute, New Delhi, to know the effect of integrated nutrient management in wheat (cv WR 544) under different planting systems.The experiment was conducted in a split plot design with 20 treatment combinations and replicated thrice, during both the years of experimentation.The field topography 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. Data were recorded on root dry weight (g/plant), root volume (cm^3/plant), root length (m/plant), root length density (cm/cm^3) and specific root length (m/g) at 45 and 90 days after sowing. The wheat variety WR 544 (Pusa Gold) is a late sown bread wheat variety having parentage Kalyan Sona/HD 1999/HD 2204/DW 38 and recommended for irrigated conditions of Delhi region, released by IARI New Delhi in 2005. It has distinguishing characters like semi-erect growth habit, very early time of ear emergence, drooping flag leaf attitude, medium ear length, medium shoulder width of lower glume with round shoulder shape, bent peduncle attitude and length of brush hair not prominent.

RESULTS AND DISCUSSION

Planting system and integrated nutrient management on root dry weight (g/plant)

The data related to root dry weight of wheat at different growth stages during the two years of experimentation were presented in Table 1. Availability of essential nutrients in adequate amounts and proportions are important for proper root development of plants, a fact amply exemplified by the data on root parameters of wheat plants as recorded in the present investigation. At both 45 and 90 DAS, FIRB planting system recorded significantly higher root dry weight over conventional planting system during both the years of study. A significant increase in dry weight of roots was observed on application of fertilizer as compared to unfertilized treatment at 45 and 90 DAS during both years of study. The treatment receiving 75% RDF + FYM + BF + Zn recorded maximum root dry weight of 1.00 g/plant during 2007-08, while during 2008-09, it was observed with treatment receiving RDF + FYM + BF + Zn (0.99 g/plant). During 2007-08, the treatments receiving RDF only, 75% RDF + FYM, 75% RDF + FYM + Zn and RDF + FYM registered significantly lower root dry weight as compared to 75% RDF + FYM + BF + Zn. During 2008-09, the treatment RDF + FYM + BF + Zn observed a significantly higher root dry weight over the treatments RDF only and 75% RDF + FYM. However, it was statistically at par with rest fertilizer receiving treatments.At 90 DAS, highest root dry weight (2.73 and 2.74 g/plant) was observed with RDF + FYM + BF + Zn during both the years of study which was significantly higher over the treatment receiving RDF only and 75% RDF + FYM. The treatment RDF + FYM + BF + Zn was followed by treatment 75% RDF + FYM + Zn which was statistically at par during both the years of study. Lowest root dry weight was registered by control at all growth stages during the year 2007-08 and 2008-09. Sepat *et al.* (2010) and Tulasa Ram and Mir (2006) were also reported similar finding while working separately at different place on wheat.

Planting system and integrated nutrient management on root volume (cm³/plant)

The data presented in Table 2 revealed the effect of different treatments on root volume of wheat during 2007-08 and 2008-09. Among planting systems, at 45 DAS significantly higher root volume (8.2 and 8.0 cm^3/plant) was

Table 1 Effect of planting system and integrated nutrient management on root dry weight (g/plant)

Treatment	45 DAS		90 DAS	
	2007-08	2008-09	2007-08	2008-09
Planting systems				
Conventional	0.81	0.80	2.35	2.34
FIRB	0.88	0.90	2.53	2.53
SEm±	0.021	0.019	0.044	0.047
LSD (P=0.05)	0.059	0.057	0.125	0.135
Nutrient management				
Control	0.43	0.44	1.48	1.48
135 kg N + 60 kg P_2O_5 + 60 kg K_2O/ha (RDF)	0.69	0.76	2.27	2.25
75% RDF + FYM	0.81	0.82	2.35	2.36
75% RDF + FYM + Zn	0.84	0.87	2.52	2.49
75% RDF + FYM + BF	0.93	0.92	2.59	2.59
75% RDF + FYM + Zn + BF	1.00	0.97	2.69	2.69
RDF + FYM	0.84	0.86	2.53	2.45
RDF + FYM + Zn	0.93	0.93	2.6	2.59
RDF + FYM + BF	0.97	0.96	2.69	2.68
RDF + FYM + Zn + BF	0.99	0.99	2.73	2.74
SEm±	0.047	0.045	0.105	0.102
LSD (P=0.05)	0.135	0.125	0.295	0.291

registered under FIRB planting as compared to conventional planting system during both the years of experimentation. Similar trend was observed at 90 DAS. The application of NPK fertilizer alone or in combination with other nutrient sources showed a significantly higher root volume of wheat at 45 and 90 DAS over the unfertilized control during both the years of study. The highest root volume (8.40 and 8.30 cm^3/plant during 2007-08 and 2008-09, respectively) of what was recorded in the treatment RDF + FYM + BF + Zn at 45 DAS. The treatment RDF + FYM + BF + Zn was at par with treatments 75% RDF + FYM + Zn, 75% RDF + FYM + BF, 75% RDF + FYM + BF + Zn, RDF + FYM, RDF + FYM + Zn and RDF + FYM + BF. The treatments which received RDF only and 75% RDF + FYM recorded significantly lower root volume than that recorded in RDF + FYM + BF + Zn. Similar trend was observed at 90 DAS during both the years of experimentation. Weaver (1926), Sepat *et al.* (2010) and Jat *et al.* (2006) were also reported identical findings.

Planting system and integrated nutrient management on root length (m/plant)

Data pertaining to root length of wheat at different growth stages during 2007-08 and 2008-09 was presented in Table 3. A perusal of data revealed that FIRB planting system recorded significantly higher root length (22.60 and 21.20 m/plant during 2007-08 and 2008-09, respectively) at 45 DAS over conventional planting system during both the years of study. Similar trend was observed at 90 DAS.Application of recommended dose of fertilizer alone or in combination with other sources of nutrient recorded a significantly higher root length at 45 and 90 DAS over unfertilized control during both the years of study. At 45 DAS, the maximum root length of 22.80 and 21.90 m/plant was observed with RDF + FYM + BF + Zn during 2007-08 and 2008-09, respectively, which was followed by treatment receiving 75% RDF + FYM + BF + Zn. The treatment RDF + FYM + BF + Zn registered a significantly higher root length over treatments receiving RDF only and 75% RDF + FYM, while rest of treatments were statistically at par. Similar trend was observed at 90 DAS during both the years of study. Alike results were reported by Aggarwal *et al.* (2006) and Ba Bomen *et al.* (2007).

Planting system and integrated nutrient management on root length density (cm/cm^3)

The data presented in Table 4 revealed the effect of different treatments on root length density during 2007-08 and 2008-09.Among planting systems, at 45 DAS significantly higher root length density (0.76 and 0.70 cm/cm^3) was observed under FIRB planting as compared to conventional planting system during years 2007-08 and 2008-09. Same trend was observed at 90 DAS during both years of study. The application of NPK fertilizer alone or in

Table 2 Effect of planting system and integrated nutrient management on root volume (cm^3/plant)

Treatment	45 DAS		90 DAS	
	2007-08	2008-09	2007-08	2008-09
Planting systems				
Conventional	7.10	6.90	13.50	13.00
FIRB	8.20	8.00	15.40	14.90
SEm±	0.12	0.15	0.27	0.28
LSD (P=0.05)	0.35	0.44	0.78	0.81
Nutrient management				
Control	5.10	5.00	9.70	9.30
135 kg N + 60 kg P_2O_5 + 60 kg K_2O/ha (RDF)	7.00	6.80	13.40	13.00
75% RDF + FYM	7.50	7.10	13.80	13.10
75% RDF + FYM + Zn	7.80	7.60	15.00	14.40
75% RDF + FYM + BF	8.20	7.90	15.20	14.80
75% RDF + FYM + Zn + BF	8.30	8.20	15.80	15.20
RDF + FYM	7.80	7.70	15.00	14.60
RDF + FYM + Zn	8.20	7.80	15.20	14.80
RDF + FYM + BF	8.30	8.10	15.50	15.00
RDF + FYM + Zn + BF	8.40	8.30	16.30	15.30
SEm±	0.24	0.35	0.59	0.61
LSD (P=0.05)	0.70	1.01	1.69	1.74

Table 3 Effect of planting system and integrated nutrient management on root length (m/plant)

Treatment	45 DAS		90 DAS	
	2007-08	2008-09	2007-08	2008-09
Planting systems				
Conventional	18.50	18.60	39.70	40.20
FIRB	22.60	21.20	44.70	45.90
SEm±	0.32	0.35	0.68	0.71
LSD (P=0.05)	0.90	1.00	1.95	2.05
Nutrient management				
Control	14.10	12.90	31.00	31.90
135 kg N + 60 kg P_2O_5 + 60 kg K_2O/ha (RDF)	19.20	18.60	39.60	40.40
75% RDF + FYM	19.30	19.10	40.20	41.40
75% RDF + FYM + Zn	21.00	20.30	43.20	43.80
75% RDF + FYM + BF	21.50	21.20	44.80	45.40
75% RDF + FYM + Zn + BF	22.30	21.70	45.50	46.30
RDF + FYM	21.20	20.80	43.40	44.00
RDF + FYM + Zn	21.40	20.90	44.00	44.70
RDF + FYM + BF	21.90	21.50	44.90	45.70
RDF + FYM + Zn + BF	22.80	21.90	45.60	46.90
SEm±	0.71	0.78	1.55	1.58
LSD (P=0.05)	2.01	2.21	4.42	4.52

conjunction with other nutrient sources showed a significantly higher root length density of wheat at 45 and 90 DAS over the unfertilized control during both years of study.The highest root length density (0.76 and 0.74 cm/cm^3 during 2007-08 and 2008-09, respectively) of wheat was observed with RDF + FYM + BF + Zn at 45 DAS. The treatment RDF + FYM + BF + Zn was statistically at par with treatments 75% RDF + FYM + Zn, 75% RDF + FYM + BF, 75% RDF + FYM + BF + Zn, RDF + FYM, RDF + FYM + Zn and RDF + FYM + BF. The treatment receiving RDF only and 75% RDF + FYM recorded significantly lower root length density over RDF + FYM + BF + Zn. Same trend was observed at 90 DAS during both years of study. These results were in close conformity of Aggarwal *et al.* (2006), Jat *et al.* (2006) and Dudh at *et al.* (1997).

Planting system and integrated nutrient management on specific root length (m/g)

Perusal of data presented in the Table 5, shows the effect of different treatments on specific root length of wheat during both the years of study. At 45 and 90 DAS, FIRB system of planting registered a higher specific root length which was statistically at par with conventional planting system during both years of study. At 45 and 90 DAS unfertilized control recorded highest specific root length during both the years 2007-08 and 2008-09. During 2007-08, lowest specific root length (22.3 m/g) at 45 DAS was recorded with 75% RDF + FYM + BF + Zn which was significantly lower than control. A significant lower root specific length (22.2 m/g) was observed with treatment RDF + FYM + BF + Zn during 2008-09 as compared to unfertilized control at 45 DAS. At 90 DAS, lowest specific root length of 16.7 m/g during both the years was recorded with RDF + FYM + BF + Zn and RDF + FYM + BF. Ahmad *et al*. (2006) and Kaur *et al*. (2006) were also noticed similar trends.

Grain 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 6.The data 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 a 11.3 per cent 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. On perusal of data on the

Table 4 Effect of planting system and integrated nutrient management on root length density (cm/cm^3)

Treatment	45 DAS		90 DAS	
	2007-08	2008-09	2007-08	2008-09
Planting systems				
Conventional	0.62	0.62	1.32	1.34
FIRB	0.76	0.70	1.49	1.53
SEm±	0.013	0.014	0.025	0.027
LSD (P=0.05)	0.037	0.04	0.073	0.076
Nutrient management				
Control	0.47	0.43	1.03	1.06
135 kg N + 60 kg P_2O_5 + 60 kg K_2O/ha (RDF)	0.64	0.62	1.32	1.34
75% RDF + FYM	0.66	0.64	1.34	1.38
75% RDF + FYM + Zn	0.70	0.67	1.44	1.46
75% RDF + FYM + BF	0.71	0.70	1.49	1.51
75% RDF + FYM + Zn + BF	0.75	0.72	1.51	1.54
RDF + FYM	0.70	0.69	1.45	1.47
RDF + FYM + Zn	0.71	0.69	1.47	1.49
RDF + FYM + BF	0.74	0.71	1.5	1.52
RDF + FYM + Zn + BF	0.76	0.74	1.52	1.56
SEm±	0.025	0.026	0.054	0.055
LSD (P=0.05)	0.073	0.077	0.153	0.157

Table 5 Effect of planting system and integrated nutrient management on specific root length (m/g)

Treatment	45 DAS		90 DAS	
	2007-08	2008-09	2007-08	2008-09
Planting systems				
Conventional	23.9	23.3	16.9	17.2
FIRB	24.6	23.5	17.7	18.1
SEm±	0.87	0.51	0.51	0.63
LSD (P=0.05)	NS	NS	NS	NS
Nutrient management				
Control	32.7	29.3	20.9	21.6
135 kg N + 60 kg P_2O_5 + 60 kg K_2O/ha (RDF)	27.7	24.6	17.5	18.0
75% RDF + FYM	23.9	23.3	17.1	17.5
75% RDF + FYM + Zn	25.0	23.3	17.1	17.6
75% RDF + FYM + BF	23.0	23.0	17.3	17.5
75% RDF + FYM + Zn + BF	22.3	22.5	16.9	17.2
RDF + FYM	25.3	24.1	17.1	18.0
RDF + FYM + Zn	22.9	22.4	16.9	17.2
RDF + FYM + BF	22.7	22.5	16.7	17.1
RDF + FYM + Zn + BF	23.1	22.2	16.7	17.1
SEm±	1.95	1.2	1.12	1.6
LSD (P=0.05)	5.41	3.42	3.25	4.61

grain yield of wheat, significant superiority of treatments receiving NPK fertilizers either in isolation or in combination with organic manures was observed over the unfertilized control during both the years of study. Among different 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. The highest yielding treatment receiving combined application of RDF + FYM + BF + Zn gave 16.78 and 14.11% 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. Comparable findings were also reported by Kumar *et al.* (2004) and Mehta (2004).

Straw yield (q/ha)

The data pertaining to straw yield of wheat as observed during 2007-08 and 2008-09 were presented in Table 6. 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 recorded significantly higher straw yield over treatments RDF only, 75% RDF + FYM + BF and RDF + FYM +Zn. Parallel results were also recorded by Tulasa Ram and Mir (2006) and Kumar *et al.* (2004).

Harvest index (%)

Harvest index represents the proportion of total dry matter of crop partitioned towards the grains that forms the economic yield. On perusal of data regarding harvest index of wheat (Table 6) significant difference between the planting systems during both the years were observed 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. Similar trends were reported by Kumar *et al.* (2004), Sepat

Table 6 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 P_2O_5 + 60 kg K_2O/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

et al. (2010) and Jat *et al.* (2006).

CONCLUSION

The root growth parameters like root dry weight, root volume, root length and root length density was favourably affected by treatment receiving fertilizer as compared to unfertilized plot at all the growth stages. However, higher values of these parameters were observed when integrated application of NPK along with FYM, biofertilizers and zinc were applied. This might have resulted from the better availability of nutrients to the growing roots; finally better grain yield was recorded. Though the study on root has its own limitation, but availability of good quality scanner made job easy. Initial root vigour could be utilized as a indicator of performance, under normal and stress condition as well.

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