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Root growth, yield and economics of wheat *(Triticum aestivum)* as affected by irrigation and tillage practices in south Bihar

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ABSTRACT

A field experiment was carried out during 3 winter seasons from 2000–01 to 2002–03 at Patna, to find out effect of tillage practices, viz. zero tillage, bed planting and conventional, and irrigation levels, viz. 3, 5, 7 and 9 cm depth on rooting behaviour, yield and economics of wheat [(*Triticum aestivum* (L.) emend. Fiori & Paol.] in Ustipsamment soils. Root characters like area (10.5 cm^2) and length (48.1 cm) were highest in bed planting, followed by conventional and zero tillage at tillering as well as flowering stages. Highest grain yield of 36.6 q/ha was obtained in zero tillage, followed by conventional tillage (34.1 q/ha) and bed planting (31.5 q/ha). Irrigation at 7 cm water depth resulted in maximum grain (34.2 q/ha) and straw yields. Highest water-use efficiency (375 kg/ha-cm) was recorded with bed planting. A significant positive linear relationship was observed between irrgation depths and root growth and grain yield.

Key words : Bed planting, Grain yield, Heavy soils, Zero tillage, Irrigation water depth, Root growth

Wheat is the second most important cereal crop after rice in Bihar. Conventionally, the crop is sown on a fine seedbed but tillage practices for wheat establishment are changing in Indo-Gangetic Plains. In north-western part of India including Haryana and Punjab, raised bed sowing is gaining popularity while in northern Uttar Pradesh as well as in few pockets of Bihar plains, zero tillage has found acceptance with the farmers.

These tillage practices (zero tillage and bed planting) influence the root growth, crop establishment and thereby water and nutrient uptake. Different establishment methods, irrigation levels and its influence on growth parameters and grain yield of wheat have not been studied systematically especially in south Bihar, the present study was undertaken to find out suitable method of sowing and optimum depth of irrigation for wheat in heavy soils.

MATERIALS AND METHODS

The field experiment was conducted during the winter seasons of 2000–01, 2001–02 and 2002–03 at Sabajpura Experimental Farm, Patna (Bihar), in clay-loam soils. Rice–wheat cropping system has been in the field since last 10 years. In past conventional puddle transplanted rice followed by conventional broadcast and ploughed wheat was taken every year. A total of 12 treatment combinations having 3 methods of tillage, zero tillage, raised bed sowing and conventional method (tractor ploughing and broadcast sowing) as control, in main plots and 4 irrigation water regimes, viz. 3 cm, 5 cm, 7 cm and 9 cm, in sub-plot treatments were laid out in split-plot design with 3 replications. Wheat 'PBW 343' was sown on 24, 24 and 17 December in 2000, 2001 and 2002 respectively at a spacing of 20 cm between the rows. Seed rate was 125 kg/ha in conventional and zero tillage and 100 kg/ha for bed planting. The fertilizer dose applied was 100, 50 and 40 kg/ha of N, P_2O_5 and K_2O. Four irrigations were given in all treatments at 4 depths (3,5,7,9 cm) at different critical stages of the crop.

The soil was Ustipsamments under Gangetic alluvium plains. The clay-loam soil with almost neutral pH (1:2 ratio) 7.3 had electrical conductivity (1:2 ratio) 0.263 dS/m, organic carbon 0.58%, available N 253 kg/ha, available P 26.5 kg/ha and available K 373 kg/ha. Stage-wise root studies were conducted by taking volumetric soil samples and using root analyser-based technique on automated quantification of roots in the laboratory. Weed parameters were also recorded. Relationship between root parameters, moisture regime and grain yield was evolved using multiple linear regression technique.

RESULTS AND DISCUSSION

Root characteristics

There was significant variation in root area of wheat due to tillage practices. The maximum root area was observed at tillering stage in case of raised bed method followed by conventional tillage and zero tillage. At flowering

age the root area was maximum in raised bed followed by zero tillage method. The maximum values were recorded at 7 cm followed by 9 cm, and the minimum values at 3 cm depth of irrigation (Table 1). The favourable tilth with lower bulk density values (1.42–1.45 g/cm^3) in raised bed compared to zero tilled soils (1.50–1.52 g/cm^3) and with a combination of irrigation level (7 cm) enhanced the root growth.

The number of finer roots with an average root diameter of 0.39 mm increased the effective root area. The total root length density of wheat at the 0 to 0.6-m profile was maximum under conventional tillage, and minimum under zero tillage, as observed by Surendra Singh *et al.* (2004). Reduced tillage system resulted in wheat root length density equivalent or even higher than the conventional tillage in a semi-arid region (Berzegar *et al.*, 2004). Differences in resistance to buckling may be more important than any differences in root elongation rate once a root reaches the strong soil (Clark *et al.*, 2003).

Root diameter was lowest in conventional tillage and highest in raised bed at tillering stage but there was no significant change in further. During initial phase of crop, primary root development in raised beds was fast as indicated by larger root diameter. The average root diameter was maximum in higher irrigation water depth (9 cm). Root length was also maximum at tillering, raised bed, and followed by conventional method and zero tillage on the other hand. (Table 1) At flowering, it remained maximum in raised bed but it was at par with zero tillage method. The inhibition of root growth by possible mechanical impedance of soil can be reduced in later stages of wheat growth. The maximum root length was observed under 9 cm depth of irrigation; however it was not superior to 7 cm at both the tillering and flowering stages. Similarly,

Table 1. Effect of tillage practice and irrigation depth on root characteristics of wheat at vegetative and reproductive stages (pooled data of 3 years)

Treatment	Root area (cm^2)		Root length (cm)		Surface density (mm^2/ml)		Root diameter (mm)	
	Tillering	Flowering	Tillering	Flowering	Tillering	Flowering	Tillering	Flowering
Tillage practice								
Conventional tillage	4.4	7.0	35.9	37.1	126.7	204.4	0.38	0.49
Zero tillage	3.8	4.3	33.1	39.9	101.3	191.9	0.39	0.41
Raised bed	5.3	10.5	41.3	48.1	113.9	267.5	0.40	0.39
CD (P=0.05)	0.9	0.5	1.0	9.2	2.2	0.9	0.02	0.02
Irrigation depth (cm)								
3	2.9	6.0	29.5	29.6	79.7	170.6	0.36	0.36
5	4.2	8.4	35.7	43.6	109.4	230.9	0.38	0.39
7	5.6	10.2	40.8	45.7	124.4	255.7	0.40	0.46
9	5.3	8.5	41.0	47.9	142.3	227.9	0.42	0.51
CD (P=0.05)	0.9	0.6	0.9	7.9	1.1	0.2	0.02	

Table 2. Effect of tillage method and irrigation water depth on grain, straw yield and water-use efficiency of wheat

Treatment	Grain yield (q/ha)				Straw yield (q/ha)				Ears (no./m^2)				Water-use efficiency			
	2000–01	2001–02	2002–03	Mean	2000–01	2001–02	2002–03	Mean	2000–01	2001–02	2002–03	Mean	2000–01	2001–02	2002–03	Mean
Tillage method																
ZT	32.6	37.0	40.2	36.6	42.3	48.6	54.4	48.4	311.9	319.5	436.6	333.6	153	178	189	173
RB	32.1	29.8	32.7	31.5	42.35	39.0	43.2	41.5	281.8	260.4	381.4	356.0	387	354	385	375
CS	32.3	32.3	37.8	34.1	42.66	42.6	50.5	45.3	303.0	295.9	402.0	307.9	135	134	158	142
CD (P=0.05)	1.8	2.3	2.8	2.3	NS	NS	NS	NS	28.5	57.3	25.5	47.4				
Irrigation depth (cm)																
3	30.9	28.8	35.8	31.8	42.04	39.1	49.7	43.6	280.7	286.4	390.5	318.2	257	240	298	265
5	33.2	29.7	37.0	33.3	42.83	37.6	47.8	42.7	307.4	290.2	405.7	334.4	166	148	185	166
7	33.5	30.8	38.3	34.2	42.89	39.0	48.8	43.6	313.5	299.2	418.9	343.8	120	110	137	123
9	31.7	29.4	36.6	32.6	41.76	38.6	47.8	42.7	293.8	292.4	411.7	332.6	88	82	102	91
CD (P=0.05)	1.8	1.7	3.1	2.2	NS	NS	NS	NS	29.9	12.4	33.9	11.1				

ZT, Zero tillage; RB, raised bed; CS, conventional sowing

root surface density at flowering stage was highest in raised bed and lowest in conventional method. Surface density at flowering stage was maximum under 7 cm irrigation level followed by 5 cm (Table 1). The lowest value was at 3 cm irrigation level. This could be due to better development of finer roots with availability of water in raised beds with time. Zhang Xi Ying *et al.* (2004) also observed that root length density of wheat in the top layer of soil (0–20 cm) was very high and the distribution of water uptake from the soil profile under high soil moisture conditions was the same as the distribution of root length density and played an important role in soil water uptake.

Grain yield

There was significant effect of tillage practice on grain and straw yields of wheat. The maximum grain and straw yields were recorded under zero tillage, followed by conventional tillage and raised bed method. Singh *et al.* (2004) also reported that wheat yield was maximum under the zero tillage condition of direct sowing.

There was significant effect of water management practices on grain yield, being maximum with 7 cm followed by 5 cm and 9 cm. The lowest grain yield was observed in 3 cm water. There was non-significant effect of water regimes on straw yield of the crop.

Relationship between root parameters, irrigation depth and grain yield

The roots play an important role in uptake of nutrients and water, which are essential for the growth of above-ground parts of the plant. The favourable soil physical conditions and improved water availability enhances root growth and thereby the yield. The regression analysis revealed that there was a significant positive linear relationship between growth of root parameters (root length and root surface density) and grain yield. The resulted relationship were (i) Grain yield = 26.18 + (0.03576* Surface density)– (0.867* Irrigation depth) and (ii) Grain yield = 19.17 + (0.5154* Root length)–(0.8555* Irrigation depth). The above relationship showed that root growth was influenced by the different depths of irrigation water applied in turn on grain yield. Similar observations were also made by Izumi *et al.* (2004) and revealed that root length per unit area had a significant positive correlation with both the total shoot biomass and yield in wheat.

Economics

Adoption of zero tillage saved total Rs 1,783/ha towards land preparation and sowing (Rs 1,233) and irrigation (Rs 451). The total benefit from yield gain and saving of returns was Rs 3,467/ha in zero tillage. Maximum benefit of Rs 5,195/ha was obtained at 7 cm irrigation depth. Under bed planting, excess amount of Rs 800/ha was incurred in crop establishment during first year but overall saving was Rs 533/ha. Although, there was a loss of Rs 1,592/ha under bed planting due to low yield, Rs 2,605/ha was saved from irrigation water application. Thus, there was a net change in benefit of Rs 1,987/ha owing to bed planting

Table 3. Economics of tillage practices and irrigation depth in wheat under heavy soils of south Bihar (pooled data of 3 years)

Treatment	Expenditure under land preparation and sowing (Rs/ha)	Total mean irrigation water applied (ha-cm)	Total irrigation cost @ Rs 167/ha-cm (Rs/ha)	Saving from irrigation over recommended 24 cm depth (Rs/ha) (a)	Saving owing to tillage practices (Rs/ha) (b)	Additional income owing to treatment over control (Rs/ha) (c)	Net change in benefit Rs/ha (a+b+c)
Tillage practice							
Zero tillage	800	21.3	3,557	451	1,233	1,783	3,467
Raised bed	2,800	8.5	1,403	2,605	533	–1,592	1,546
Conventional tillage	2,000	24.0	4,008				
Zero tillage							
3 cm		21.1	3,508	500	1,233	566	2,299
5 cm		21.2	3,540	468	1,233	1,751	3,452
7 cm		21.4	3,574	434	1,233	3,528	5,195
9 cm		21.6	3,600	408	1,233	–320	1,321
Raised bed							
3 cm		8.0	1,336	2,659	533	1,205	1,987
5 cm		8.3	1,389	2,619	533	1,422	1,730
7 cm		8.5	1,418	2,623	533	2,798	358
9 cm		8.6	1,437	2,571	533	2,735	369

Grain @ 550 in first year and Rs 600 in second and third year; straw @ 100/q

n 3 cm water depth when compared to conventional wing with recommended dose of irrigation (Table 3). The highest water-use efficiency (WUE) of 375 kg/ha-cm was recorded in raised bed method. The WUE in zero tillage (173) was higher than that in conventional system (142), but both were at par. This might be due to high saving of irrigation water in only first irrigation in ZT. Increasing depth of irrigation lowered the WUE. An irrigation depth of 5 cm was found significantly superior to 9 cm for WUE and difference in WUE between 5 and 7 cm irrigation depth was at par (Table 2).

Thus raised bed method of crop establishment and 7 cm irrigation level resulted in better grain yield as well as root growth of wheat compared to the zero and conventional tillage. A linear positive relationship was found between different root growth parameters, irrigation depth and grain yield.

REFERENCES

Barzegar, A.R., Mossavi, M.H., Asoodar, M.A. and Herbert, S.J. 2004. Root mass distribution of winter wheat as influenced by different tillage systems in semi-arid region. *Journal of Agronomy* 3(3) : 223–228.

Clark, L.J., Whalley, W.R. and Barraclough, P.B. 2003. How do roots penetrate strong soil? *Plant and Soil* **255** : 93–104.

Izumi, Y., Uchida, K. and Iijima, M. 2004. Crop production in successive wheat–soybean rotation with no-tillage practice in relation to the root system development. *Plant Production Science* **7** (3) : 329–336.

Singh, Surendra, Tripathi, R.P., Sharma, Peeyush and Kumar, Ravindra. 2004. Effect of tillage on root growth, crop performance and economics of rice *(Oryza sativa)*–wheat *(Triticum aestivum)* system. *Indian Journal of Agricultural Sciences* **74** (6) : 300–304.

Zhang XiYing, Pei Dong and Chen SuYing. 2004. Root growth and soil water utilization of winter wheat in the North China Plain. *Hydrological Processes* **18** (12) : 2,275–2,287.