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Effect of crop establishment methods and irrigation scheduling (WUE) on performance of wheat in North Bihar (*Triticum aestivum* L.)

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Abstract
An experiment with four establishment methods (E_1 - Conventional tillage, E_2 - Zero tillage, E_3-Bed planting and E_4-System of wheat intensification method) in the main plots and four levels of irrigation (I_1 - 3 irrigations at 20, 50 and 80 DAS, I_2 - 4 irrigations at 20, 40, 70 and 90 DAS, I_3 - 5 irrigations at 20, 40, 60, 80 and 100 DAS and I_4 - IW/CPE ratio 1.0) in the sub plots was conducted at Dr. R. P. C. A.U. research farm, Pusa during *rabi* 2011-12 in split plot design with three replications. The results showed that the growth characters like number of tillers/m^2, LAI, dry matter accumulation, CGR, panicles/m^2, WUE, no. of grains/panicle, 1000 grain weight, gross and net return were higher under conventional tillage (CT) as compared to Bed planting and SWI methods. The maximum B: C ratio was obtained with zero tillage (ZT). The maximum WUE was recorded with 3 irrigations. Grain yield, WUE, gross return, net return and B: C ratio were positively influenced by interaction between establishment methods and irrigation levels. However, the maximum Benefit: Cost ratio of 1.98 with net return of 35973 ₹ /ha was fetched with Zero tillage at irrigation level I_1 receiving 3 irrigations.

Keywords: Establishment methods, CGR, WUE, zero tillage and wheat

Introduction
plays an important role in national food adequacy and stabilizing the food grain production in the country with ascending levels. At present, the country occupies the second highest position after China among wheat growing nations of the world. The area under wheat cultivation in India has been increased very rapidly from 12.6 to 29.25 million hectares since 1965 to 2010, and production has gone up from 10.4 to 85.93 million tonnes. Similarly, productivity has also jumped from 827 to 2938 kg/ha during aforesaid period. In Bihar, it is grown in 2.16 million hectares area with production and productivity of 5.05 million tonnes and 2335 kg/ha, respectively (Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Govt. of India, 2015-16) which is much below the level of national as well as world average productivity. According to Kumar *et al.*, 2017; Idnani and Kumar (2012) [3, 1], under Zero tillage condition, it was found that if stubbles from the previous crop were left and perennial weeds were controlled, there was hardly any need for additional soil cultivation to realize high yields.

Proper establishment methods with matching agronomic management practices particularly irrigation levels could pave the way for increasing economic wheat production in rice-wheat cropping system. Mehta *et al.*, (2000) [5] suggest that the timely sown ZT wheat crop yielded 6 per cent and 15 per cent improvement in the more productivity than the timely sown CT wheat crop, because of more efficient fertilizer use and less germination of grassy weeds. Sidhu *et al.*, 2015 [9] and Singh *et al.*, 2016; [10] devised that the gain yield from timely planted, ZTD was 9 per cent and in bed planting Furrow Irrigated Raised Bed (FIRB) practise, it has increased dramatically in the high yielding irrigated wheat growing areas of north western Mexico. This system is getting increased attention as it promotes crop diversification and provides an alternative means of increasing productivity and growth for wheat crop. Bed planting system is

now being assessed for suitability in the Indian Subcontinent. Two of the major constraints to high yields in north Western India and Pakistan are weeds and lodging. Both can be reduced in bed planting system. System of Wheat Intensification (SWI) method also created very good growing conditions for wheat through modified soil, water, plant and nutrient management. In the second method, pre-germinated seeds primed in hot water, cow urine, vermicompost, jaggery along with bavistin are sown by dibbling method at 20 cm row to row and plant to plant spacing with seed rate of 25 kg/ha. About 70% area under wheat in India is said to have irrigation facility. Besides, it is also essential to assess accurately the drop in yield with reduction in number of irrigation, which will present a clear picture about the water use efficiency. Recent study on timely sowing and irrigation, tillage interactions are likely to play a significant role in improving the productivity of wheat, where irrigation levels and crop establishment methods can play a dominant role in maximizing the wheat yield and water use efficiency.

Materials and Methods

The field experiment was conducted during the *Rabi* season of 2011-2012 at Pusa research farm of Dr. Rajendra Prasad Central Agricultural University, Bihar. In respect of mean temperature and relative humidity at 7 AM. The maximum temperature during the crop season varied from 20.3 to 36.2 ^{0}C which was 0.9 to 3.9^{0}C less than normal from November 2011 to March 2012 but during April 2012 was only 0.1^{0}C higher than normal. The minimum temperature during the crop period varied from 9.2 to 20.7 ^{0}C which was 0.3 to 1.3 ^{0}C higher than normal except during February and March 2012 in which month minimum temperature was 0.6 to 2.2^{0}C less than normal. Rainfall became the major factor as 41.0 mm of rainfall was received during 1st and 2nd week of January 2012 which coincided tillering stage. The results of soil analysis presented in Table 1 and 2 indicated that the soil of the experimental plot was sandy loam in texture, alkaline in reaction and low in available nitrogen, phosphorus and medium in potassium content. The wheat variety HD 2733 had sown in split plot design with three replications. The plot has 4 main and sub plot treatments. The gross and net plot size was 5.0 m x 4.0 m and 4.0 m x 3.0 m respectively. The common fertilizer dose was 120kg N, 60kg P_2O_5 and 40kg K_2O/ha. The total number of replications were three. Establishment methods – Four (Main plot): E_1: Conventional tillage; E_2: Zero tillage sowing; E_3: Bed planting; E_4: System of Wheat Intensification (SWI method). Irrigation levels – Four (Sub plot): I_1: 3 irrigations at 20, 50 and 80 DAS; I_2: 4 irrigations at 20, 40, 70 and 90 DAS; I_3: 5 irrigations at 20, 40, 60, 80 and 100 DAS; I_4: IW/CPE ratio 1.0 (after first irrigation at 20 DAS).

Harvest index (%)

Then the grains and straw were weighed separately and the harvest index was calculated with the help of the following formula.

$$\text{Harvest Index} = \frac{\text{Grain yield}}{\text{Grain yield} + \text{Straw yield}} \times 100$$

Soil moisture studies

$$\text{Moisture}(\%) = \frac{\text{Weight of wet soil} - \text{Weight of dry soil}}{\text{Weight of dry soil}} \times 100$$

Water requirement

$$WR = IR + ER + [\sum \frac{Mbi - Mei}{100}] \times BDi \times Di$$

Water use efficiency (WUE) (kg/ha-cm)

It is calculated by the ratio of grain yield (kg/ha) and total water requirement per cm area.

$$\text{WUE (kg/ha-cm)} = \frac{\text{Y (kg/ha)}}{\text{WR (cm)}}$$

Where,
WUE = Water use efficiency (kg/ha-cm)
Y stands for grain yield (kg/ha) and WR stands for total water requirement (cm).

Results and Discussion

In the present study, growth characters like plant height, number of tillers/m^2, leaf area index, dry matter production and crop growth rate which are directly or indirectly responsible for modifying the yield attributing characters and finally the grain yield were studied at different growth stages. Tillering per unit area is the function of plant density and tillering ability of the crop. The tillers/m^2 were higher in Zero tillage (ZT) compared to Bed planting and SWI method. The maximum numbers of tillers were recorded at 60 DAS (Thapa *et al.*, 2010; Sidhu *et al.*, 2015) [11, 9]. LAI is closely related to grain production because this affects the amount of photosynthate accumulation. LAI increased up to 60 DAS, highest LAI was observed with CT at all the growth stages (Mukherjee, 2008) [6]. The maximum value of dry matter (g/m^2) and CGR (g/m^2/day) were recorded in CT. Growth characters studied except at early stages showed variation due to irrigation levels. The highest plant height, number of tillers/m^2, LAI, dry matter accumulation and CGR were recorded with the irrigation level I_3 receiving 5 irrigations at 20, 40, 60, 80 and 100 DAS which was higher than irrigation level I_1 receiving 3 irrigations at 20, 50 and 80 DAS and I_4 receiving 4 irrigations based on IW/CPE ratio of 1.0.

The number of panicles/m^2 was higher with CT, as the crop geometry helped to have more plant population in CT and ZT methods. The number of panicles/plant was the highest in SWI method. (Singh *et al*., 2006 and Sagar *et al*., 2017) [10, 8]. The highest 1000-grain weight was recorded with Bed planting. Among the establishment methods the highest grain yield, straw yield was recorded with CT (Jha *et al.* 2011; Victor *et al.*, 2012 and Sidhu *et al.*, 2015) [2, 12, 9]. The growth and yield attributes were best expressed under higher levels of irrigation i.e. five irrigations applied at 20, 40, 60, 80 and 100 DAS (*Singh et al.*, 2016) [10].

The treatments having higher number of ear heads per unit area, higher number of grains per ear head and greater test weight were bound to give comparatively higher yields. (Parihar and Tiwari, 2003; Kumar *et al.* 2017) [7, 3]. The maximum grain yield was recorded with irrigation level I_3 receiving 5 irrigations in CT. The soil moisture study was conducted to investigate water use efficiency. Although the available soil moisture content before sowing (82.04%), at first irrigation (72.04%) and other irrigations was the highest in zero tillage. After first irrigation, the available soil moisture content was above 60% in all the irrigation levels except in irrigation level I_4 receiving 4 irrigations at 20, 65, 89 and 105 DAS in Zero tillage and at 20,

61, 84 and 102 DAS in other establishment methods. The highest water requirement was at irrigation level I_3 receiving 5 irrigations followed by I_2 and I_4 both receiving 4 irrigations and I_1 receiving 3 irrigations. The highest water use efficiency (WUE) was recorded with CT method of establishment (Singh *et al.*, 2016) [10]. Higher WUE was recorded with ZT at irrigation level I_1 receiving 3 irrigations at 20, 50 and 80 DAS. This shows that grain yield was higher per unit of water use at this level of irrigation in ZT and CT.

The highest gross, net return (₹/ha) and B: C ratio was obtained with CT, which was higher than bed planting and SWI method. The maximum gross and net return was recorded with irrigation level I_3 receiving 5 irrigations which was superior over all other irrigation levels. The maximum B: C ratio was recorded equally with I_2 receiving 4 irrigations and I_3 receiving 5 irrigations. The maximum net return of 39015 ₹/ha with B: C ratio 1.66. However, the maximum BCR of 1.98 with net return of 35973 ₹/ha was fetched with ZT. (Idnani and Kumar, 2012; Sagar *et al.* 2017) [1, 8]. Consequently, growth, yield attributes and yield sowing of wheat by ZT as compared to CT method appears to be more beneficial. 5 irrigations applied at 20, 40, 60, 80 and 100 DAS or 4 irrigations applied at 20, 40, 70 and 90 DAS is found to be optimum.

Table 1: Plant height (cm) as affected by different treatments at different crop growth stages

Establishment methods	30 DAS	60 DAS	90 DAS	At harvest
E_1 (Conventional tillage)	18.11	39.56	84.15	87.66
E_2 (Zero tillage)	17.90	39.17	82.27	85.71
E_3 (Bed planting)	18.20	38.13	80.08	83.38
E_4 (SWI method)	18.27	37.42	78.38	81.69
S.Em. ±	0.31	0.67	1.38	1.28
CD (P=0.05)	NS	NS	NS	NS
Irrigation levels				
I_1 (3 irrigations at 20, 50 and 80 DAS)	18.06	38.21	79.53	82.06
I_2 (4 irrigations at 20, 40, 70 and 90 DAS)	18.13	39.28	81.88	85.29
I_3 (5 irrigations at 20, 40, 60, 80 and 100 DAS)	18.11	39.33	84.70	88.24
I_4 (IW/CPE ratio 1.0)	18.18	37.46	78.77	82.85
S.Em. ±	0.31	0.73	1.53	1.42
CD (P=0.05)	NS	NS	4.48	4.15

Table 2: Number of tillers/m^2 as affected by different treatments at different crop growth stages

Establishment methods	30 DAS	60 DAS	90 DAS	At harvest
E_1 (Conventional tillage)	249	565	469	376
E_2 (Zero tillage)	241	550	457	366
E_3 (Bed planting)	205	479	378	303
E_4 (SWI method)	165	434	344	275
S.Em. ±	4.59	7.15	5.85	7.97
CD (P=0.05)	15.88	24.75	20.25	27.57
Irrigation levels				
I_1 (3 irrigations at 20, 50 and 80 DAS)	214	500	388	311
I_2 (4 irrigations at 20, 40, 70 and 90 DAS)	209	520	420	336
I_3 (5 irrigations at 20, 40, 60, 80 and 100 DAS)	219	522	443	394
I_4 (IW/CPE ratio 1.0)	218	486	397	318
S.Em. ±	4.36	6.54	5.27	6.98
CD (P=0.05)	NS	19.09	15.39	20.11

Table 3: Leaf area index (LAI) as affected by different treatments at different crop growth stages

Establishment methods	30 DAS	60 DAS	90 DAS
E_1 (Conventional tillage)	0.78	4.28	3.77
E_2 (Zero tillage)	0.75	4.17	3.67
E_3 (Bed planting)	0.64	3.63	3.04
E_4 (SWI method)	0.51	3.28	2.76
S.Em. ±	0.01	0.05	0.05
CD (P=0.05)	0.05	0.19	0.16
Irrigation levels			
I_1 (3 irrigations at 20, 50 and 80 DAS)	0.67	3.79	3.12
I_2 (4 irrigations at 20, 40, 70 and 90 DAS)	0.65	3.94	3.37
I_3 (5 irrigations at 20, 40, 60, 80 and 100 DAS)	0.68	3.95	3.56
I_4 (IW/CPE ratio 1.0)	0.68	3.68	3.19
S.Em. ±	0.01	0.05	0.04
CD (P=0.05)	NS	0.14	0.12

Table 4: Dry matter production g/m^2 as affected by different treatments at different crop growth stages

Establishment methods	30 DAS	60 DAS	90 DAS	At harvest
E_1 (Conventional tillage)	24.71	225.28	507.15	928.83
E_2 (Zero tillage)	23.97	219.09	493.31	899.76
E_3 (Bed planting)	20.32	191.40	427.07	782.30
E_4 (SWI method)	16.32	173.75	378.75	690.39
S.Em. ±	0.46	4.50	6.43	10.91
CD (P=0.05)	1.58	15.56	22.25	37.77
Irrigation levels				
I_1 (3 irrigations at 20, 50 and 80 DAS)	21.27	199.92	425.67	777.99
I_2 (4 irrigations at 20, 40, 70 and 90 DAS)	20.75	207.75	461.33	843.14
I_3 (5 irrigations at 20, 40, 60, 80 and 100 DAS)	21.73	208.07	488.25	892.28
I_4 (IW/CPE ratio 1.0)	21.57	193.78	431.03	787.86
S.Em. ±	0.43	4.19	5.81	11.96
CD (P=0.05)	NS	NS	16.97	34.91

Table 5: Crop Growth Rate (g/day/m^2) as affected by different treatments at different crop growth stages.

Establishment methods	30 DAS	60 DAS	90 DAS	At harvest
E_1 (Conventional tillage)	0.83	6.69	9.40	9.37
E_2 (Zero tillage)	0.80	6.50	9.14	9.03
E_3 (Bed planting)	0.68	5.70	7.86	7.90
E_4 (SWI method)	0.55	5.25	6.83	6.93
S.Em. ±	0.02	0.13	0.19	0.10
CD (P=0.05)	0.05	0.45	0.67	0.36
Irrigation levels				
I_1 (3 irrigations at 20, 50 and 80 DAS)	0.71	5.96	7.53	7.83
I_2 (4 irrigations at 20, 40, 70 and 90 DAS)	0.69	6.23	8.45	8.49
I_3 (5 irrigations at 20, 40, 60, 80 and 100 DAS)	0.73	6.21	9.34	8.98
I_4 (IW/CPE ratio 1.0)	0.72	5.74	7.91	7.93
S.Em. ±	0.01	0.12	0.20	0.14
CD (P=0.05)	NS	0.36	0.59	0.41

Table 6: Grain yield (q/ha) as influenced by establishment methods and irrigation levels and their interaction

Establishment methods	Irrigation levels				Mean
	I_1	I_2	I_3	I_4	
E_1 (Conventional tillage)	38.60	41.77	43.71	40.94	41.25
E_2 (Zero tillage)	39.27	40.74	41.52	38.92	40.11
E_3 (Bed planting)	33.39	36.35	37.69	35.74	35.79
E_4 (SWI method)	26.87	31.92	38.71	25.46	30.74
Mean	34.53	37.69	40.41	35.27	
Source			S.Em. ±		CD (P=0.05)
Establishment methods (E)			0.88		3.06
Irrigation levels (I)			0.78		2.27
Sub treat. mean at same level of main			1.56		4.54
Main treatment mean at same or different level of sub treatment			1.61		4.96

Table 7: Straw yield (q/ha) as influenced by establishment methods and irrigation levels and their interaction

Establishment methods	Irrigation levels				Mean
	I_1	I_2	I_3	I_4	
E_1 (Conventional tillage)	53.78	56.79	58.96	55.71	56.31
E_2 (Zero tillage)	54.32	54.54	55.66	53.08	54.40
E_3 (Bed planting)	43.54	47.64	48.75	45.60	46.38
E_4 (SWI method)	37.12	44.51	49.91	35.58	41.78
Mean	47.19	50.87	53.32	47.49	
Source			S.Em. ±		CD (P=0.05)
Establishment methods (E)			0.95		3.30
Irrigation levels (I)			1.08		3.14
Sub treat. mean at same level of main			2.15		NS
Main treatment mean at same or different level of sub treatment			6.64		7.49

Table 8: Harvest index (%) as influenced by establishment methods and irrigation levels and their interaction

Establishment methods	Irrigation levels				Mean
	I_1	I_2	I_3	I_4	
E_1 (Conventional tillage)	41.80	42.46	42.62	42.36	42.31
E_2 (Zero tillage)	41.97	42.75	42.78	42.31	42.45
E_3 (Bed planting)	43.41	43.27	43.61	43.89	43.55
E_4 (SWI method)	42.03	41.68	43.71	41.67	42.27
Mean	42.30	42.54	43.18	42.56	

Source	S.Em. ±	CD (P=0.05)
Establishment methods (E)	0.82	NS
Irrigation levels (I)	0.78	NS
Sub treat. mean at same level of main	1.56	NS
Main treatment mean at same or different level of sub treatment	6.62	6.33

Table 9: Periodical soil moisture content (%) before sowing, at each irrigation and harvest.

Treatments (Establishment methods)	Moisture% at the time of sowing	Moisture% at 1st common irrigation	Moisture% at 2nd irrigation	Moisture% at 3nd irrigation	Moisture% at 4th irrigation	Moisture% at 5th irrigation	Moisture% at harvest
E_1 (Conventional tillage)	18.79 (79.96)	16.27 (69.23)	15.21 (64.72)	14.87 (63.28)	14.58 (62.04)	14.47 (61.57)	12.50 (53.19)
E_2 (Zero tillage)	19.28 (82.04)	16.93 (72.04)	16.63 (70.76)	16.36 (69.62)	15.09 (64.21)	14.96 (63.66)	12.37 (52.64)
E_3 (Bed planting)	18.72 (79.66)	16.09 (68.47)	15.08 (64.17)	14.59 (62.08)	14.22 (60.51)	14.17 (60.30)	12.16 (51.74)
E_4 (SWI method)	18.27 (79.87)	16.35 (69.57)	15.32 (65.19)	14.98 (63.74)	14.70 (62.55)	14.59 (62.09)	12.40 (52.76)
Irrigation levels							
I_1 (3 irrigations at 20, 50 and 80 DAS)	18.94 (80.60)	16.46 (70.04)	15.45 (65.74)	15.17 (64.55)	-	-	11.70 (49.79)
I_2 (4 irrigations at 20, 40, 70 and 90 DAS)	18.87 (80.30)	16.40 (69.79)	16.49 (70.17)	15.23 (64.81)	14.95 (63.62)	-	12.01 (51.11)
I_3 (5 irrigations at 20, 40, 60, 80 and 100 DAS)	18.85 (80.21)	16.41 (69.83)	16.52 (70.30)	16.47 (70.08)	15.38 (65.45)	14.55 (61.91)	12.75 (54.26)
I_4 (IW/CPE ratio 1.0)	18.90 (80.43)	16.37 (69.66)	13.78 (58.64)	13.92 (59.23)	13.61 (57.91)	-	12.97 (55.19)

Figures in parenthesis denote percentage of available soil moisture

Table 10: Total water requirement as affected by different irrigation levels

Irrigation levels	No. of irrigation	Irrigation water applied (cm)	Effective rainfall (cm)	Soil profile contribution (cm)	Total water requirement (cm)
I_1 (3 irrigations at 20, 50 and 80 DAS)	3	13.9	4.75	3.17	21.82
I_2 (4 irrigations at 20, 40, 70 and 90 DAS)	4	19.9	4.75	3.00	27.65
I_3 (5 irrigations at 20, 40, 60, 80 and 100 DAS)	5	25.9	4.75	2.67	33.32
I_4 (IW/CPE ratio 1.0)	4	19.9	4.75	2.60	27.25

Table 11: Water use efficiency (kg/ha-cm) as influenced by establishment methods and irrigation levels and their interaction

Establishment methods	Irrigation levels				Mean
	I_1	I_2	I_3	I_4	
E_1 (Conventional tillage)	176.90	151.07	131.19	150.23	152.35
E_2 (Zero tillage)	179.96	147.35	124.61	142.82	148.69
E_3 (Bed planting)	153.02	131.45	113.12	131.16	132.19
E_4 (SWI method)	123.14	115.44	116.17	93.44	112.05
Mean	158.26	136.33	121.27	129.41	

Source	S.Em. ±	CD (P=0.05)
Establishment methods (E)	3.34	11.58
Irrigation levels (I)	2.89	8.43
Sub treat. mean at same level of main	5.78	16.86
Main treatment mean at same or different level of sub treatment	6.02	18.47

Table 12: Gross return (₹/ha) as influenced by establishment methods and irrigation levels and their interaction

Establishment methods	Irrigation levels				Mean
	I_1	I_2	I_3	I_4	
E_1 (Conventional tillage)	53229	57390	59987	56253	56715
E_2 (Zero tillage)	54090	55851	56927	53498	55092
E_3 (Bed planting)	45598	49671	51410	48657	48834
E_4 (SWI method)	37006	44023	52773	35129	42233
Mean	47481	51734	55275	48384	

Source	S.Em. ±	CD (P=0.05)
Establishment methods (E)	1012	3502
Irrigation levels (I)	907	2647
Sub treat. mean at same level of main	1814	5294
Main treatment mean at same or different level of sub treatment	1868	5453

Table 13: Net return (₹/ha) as influenced by establishment methods and irrigation levels and their interaction

Establishment methods	Irrigation levels				Mean
	I_1	I_2	I_3	I_4	
E_1 (Conventional tillage)	34055	37316	39015	36179	36641
E_2 (Zero tillage)	35973	36834	37010	34481	36075
E_3 (Bed planting)	26424	29597	30436	28583	28760
E_4 (SWI method)	11919	18036	25886	9142	16246
Mean	27093	30446	33087	27096	
Source			S.Em. ±		CD (P=0.05)
Establishment methods (E)			1012		3502
Irrigation levels (I)			907		2647
Sub treat. mean at same level of main			1814		5294
Main treatment mean at same or different level of sub treatment			1818		5443

Table 14: Benefit: Cost ratio as influenced by establishment methods and irrigation levels and their interaction

Establishment methods	Irrigation levels				Mean
	I_1	I_2	I_3	I_4	
E_1 (Conventional tillage)	1.78	1.86	1.66	1.80	1.78
E_2 (Zero tillage)	1.98	1.94	1.86	1.81	1.90
E_3 (Bed planting)	1.38	1.48	1.45	1.42	1.43
E_4 (SWI method)	0.47	0.69	0.97	0.35	0.62
Mean	1.40	1.49	1.49	1.35	
Source			S.Em. ±		CD (P=0.05)
Establishment methods (E)			0.06		0.20
Irrigation levels (I)			0.05		NS
Sub treat. mean at same level of main			0.10		0.28
Main treat. mean at same or different level of sub treat.			0.10		0.29

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