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Research Paper

Pre-irrigation timing and sowing-method impact on wheat (*Triticum aestivum*) after *toria* (*Brassica rapa*) on yield, energy indices, water productivity and soil properties

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ABSTRACT

An on-farm research study was carried out during the winter (*rabi*) season of 2013–15 at Morena, Madhya Pradesh to study the impact of irrigation timing and sowing methods on yield, energy indices, water productivity and soil properties in wheat (*Triticum aestivum* L.) when grown after harvesting of *toria* (*Brassica rapa*). Different sowing times included sowing of crop after pre-irrigation (CS) and dry sowing and irrigation for germination (DS), while sowing methods included conventional tillage (CT), zero tillage (ZT) and happy seeder (HS). Results of wheat seeding with DS methods significantly influenced the growth parameters, grain, stover and protein yield, net profit, benefit: cost (B : C) ratio, energy outcomes as compared to the CS. Similarly, the maximum growth characters, grain, stover and protein yield, economic benefits, energy outcomes and water productivity (WP) were recorded with HS, followed by ZT and minimum with CT. The increase in grain yield- (12.5%) was observed with DS as compared to CS. Monetary savings of ₹3,990/ha was saved with ZT, followed by HS (₹3,260/ha) as compared with a total cost of production under CT. Results also revealed that, savings of energy inputs were 12.8% with ZT, followed by 12.3% with HS compared with total energy inputs with CT. Total water use (TWU) with CS method was significantly higher than DS, whereas the reverse trend was observed in WP. Similarly, the TWU of wheat was significantly higher in CT than with ZT and HS, whereas maximum WP was recorded with HS, followed by ZT and the minimum with CT. After harvesting of wheat, physico-chemical properties also improved with HS, followed by ZT and CT.

Key words **:** Sowing methods, Pre-sowing irrigation, Yield, Energy indices, Water productivity, Soil properties, Wheat

Maize (*Zea mays* L.)–wheat (*Triticum aestivum* L.) is the third important cropping system after rice (*Oryza sativa* L.)–wheat and rice–rice in India and occupies about 1.3 m ha land (Sinha *et al*., 2014) and contributes 2.3% in food basket (Jat *et al*., 2011). Earlier intensive cropping maize–*toria*–wheat was an potential and economically viable system in North-Western and Central India on upland plains of alluvial soils from 1970 to 1990. However, this intensive cropping system has now almost extinct, due to effect of climate-changing (shrinking of winter season and terminal heat stress), non-availability of short-duration *toria* varieties and seeding implements such as zero-till seed-cum-fertilizer drill or happy seeder. Overall, Gupta *et al.* (2000) observed a 1% decrease in wheat yield (32 kg/day/ha) for every day that wheat seeding was delayed after mid-November.

After harvesting of *toria*, wheat sowing is delayed due to late maturity of *toria* in the month of December. Sowing of wheat was further delayed by 10 to 15 days due to tillage operations for seed bed preparations after pre-sowing irrigation. In addition to this, land preparation requires high input of energy which increases the cost of cultivation and causes reduction in yield and quality of wheat Singh *et al.,* (2019). Delayed sowing of wheat requires more inputs like seed, nutrient, irrigation, *etc.* and crop is also adversely effected by terminal heat (Singh *et al*., 2020). To overcome the above problems, tillage and crop-establishment techniques with zero-tillage (ZT) methods and management of pre-sowing irrigation are the ways to mitigate the adverse

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effects on wheat under late-sown conditions after *toria*. The objective of the present study was to ensure timely sowing of wheat after harvesting of *toria* for greater yield, quality, income and soil properties with adjustment of pre-sowing irrigation and sowing methods. Keeping the above points in view, an on-farm research study was undertaken to investigate the effect of timing of pre-sowing irrigation and sowing methods on wheat after harvesting of *toria* under intensive cropping system.

MATERIALS AND METHODS

On-farm trials were conducted using 5 locations in alluvial soils at Nitahara Village of District Morena comes under Zonal Agriculture Research Station, Rajmata Vijayarage Scindia Krishi Vishwa Vidyalaya of Madhya Pradesh, India, for 2 years (2013–14 and 2014–15). The study area lies between 26.4103° N, 77.9367° E, with an altitude of 177 m. District Morena is categorized under the Gird Agro-climatic zone. The climate is characterized as semi-arid, extremely cold during December–January (–1.0°C minimum temperature) and hot during May–June (49°C maximum temperature). The major climatic vulnerabilities of this zone for wheat crops are drought, terminal heat, and occasional winter rains. The weekly average of the maximum and minimum relative humidity ranges from 38.0 to 91.1% and 23.8 to 89.0% respectively. The average annual rainfall of the experimental area is 701 mm, mostly concentrated July and August. The weekly average minimum and maximum temperature, relative humidity, total pan evaporation and rainfall during the wheat crop period are presented in Fig. 1. The soil of the experimental site was sandy loam, having bulk density 1.49 to 1.52 Mg/m^3 in 0–15 cm soil depth, infiltration rate (IR) 4 to 6 mm/h and effective soil depth 110 to 130 cm. Other soil characteristics include deficient in organic carbon (OC), available nitrogen, low to medium in phosphorus, sulphur, zinc, and medium in available potassium (Table 1).

The treatment consisted of a time of pre-sowing irrigation, *viz.* DS, dry sowing of wheat just after harvest of *toria* and irrigation for germination (17 and 19 December of 1st and 2nd years); CS, after harvesting of *toria* sowing of wheat after pre-irrigation (29 and 31 December 1st and 2nd

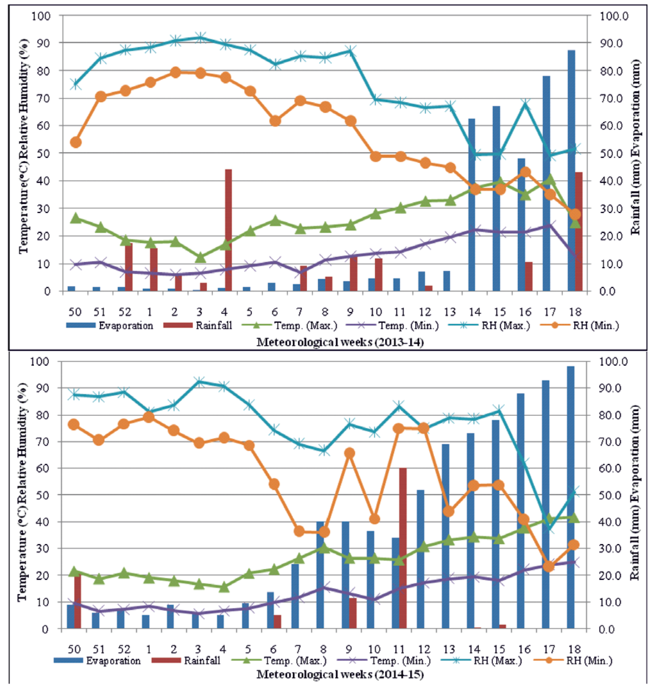

Fig. 1. Weekly meteorological data during wheat-crop period

years) in mainplots. The sowing technique in sub-plots such as conventional tillage sowing after 4 ploughing by cultivator with plunking and sowing of wheat with single box seed drill (CT), while direct seeding in zero tillage (ZT) and happy seeder (HS). The trails were laid out in split-plot design with 5 replications. The recommended dose of nutrients for this zone was 100 kg N, 60 kg P_2O_5, 40 kg S and 20 kg $ZnSO_4$/ha for wheat. The full dose of P, S, Zn and half dose of N was applied basal in wheat crop and the remaining N at the panicle-initiation stage. The sources of N, P and S were urea, diammonium phosphate and elemental sulphur respectively. A variety of wheat 'MP 4010' was sown after harvest of *toria* and package of practices were followed as per recommendation.

At maturity, the crops were harvested manually at a height of 30 cm for *toria* and 10 cm for wheat of HS seeding plots, while traditionally practices 10 cm for *toria* and 5 cm for wheat in ZT and CT plots. After the harvesting of wheat crop, grain and stover yields were recorded. The

Table 1. Physico-chemical properties of experimental field in different locations

Locations	Soil texture	*p*H	Electrical conductivity (dS/m)	Organic carbon (g/kg)	Bulk density (Mg/m^3)	Infilration (mm/h)	Available nutrients				
							N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)	S (kg/ha)	Zn (mg/kg)
L-1	Sandy loam	7.7	0.39	2.7	1.59	05	145	9.4	305	8.5	0.60
L-2	Sandy loam	7.9	0.40	3.2	1.60	05	168	9.9	290	9.8	0.45
L-3	Sandy loam	7.6	0.28	4.1	1.57	06	174	10.7	318	11.8	0.52
L-4	Sandy loam	8.1	0.53	2.9	1.51	04	151	9.5	360	10.9	0.49
L-5	Sandy loam	7.6	0.31	3.4	1.49	06	160	11.4	299	12.5	0.71

protein content was determined by multiplying 6.25 in N content in grain. Soil samples were collected from 0 to 15 cm depth before sowing and at harvesting of the crop from 3 locations within a plot. The freshly collected soil samples were mixed thoroughly, air-dried, crushed to pass through a 2-mm sieve and stored in plastic jars before analysis. The organic carbon was analyzed by Walkley and Black method (1934), available N by Kjeltec-II auto analyzer, P by Olsen *et al.* (1954), S by Chesnin and Yien (1950) and K by NH_4OAc and Zn from DTPA extraction. The bulk density (0–15 and 15–30 cm), infiltration rate after saturation of soil was measured after harvesting of crop using a double-ring infiltrometer. Energy input and output were calculated by using the procedure described by Devasenapathy *et al.* (2009). Energy indices were calculated as per Singh *et al.* (2018). Economics of treatments was also computed taking in to account the prevailing market prices for inputs and outputs. The benefit: cost ratio net returns (NR) were calculated.

Soil water content was measured gravimetrically in a 0–120 cm soil profile at 15 cm increments for the first two layers, and at 30 cm subsequently. The total water-use (TWU) and water productivity (WP) were computed as:

TWU (m^3/ha) = Rainfall + Irrigation water + soil-water depletion – runoff

WP (kg grain/m^3 of water) = Grain yield (kg/ha)/TWU (m^3/ha)

RESULTS AND DISCUSSION

Growth and yield of wheat

Growth yield components, *viz.* plants/m^2, plant height, tillers/plant, spike length, grains/spike, 1,000-grain weight, and grain, stover and protein yields were significantly higher under DS than CS method (Table 2). The treatment of CS had significantly higher total days of the emergence of wheat plant (24 days) compared with DS (9 days) after harvesting of *toria*. The highest number of plant/m^2 (209), plant height (80.51 cm), tillers (5.91/plant), spike length (7.84 cm), grains/spike (58.79), 1,000-grain weight (40.3 g) of wheat were recorded with DS as compared to CS treatment. Additional yield of wheat grain 0.47 t/ha (+12.5%) and stover 0.44 t/ha (+9.4%) was obtained with DS as compared to CS treatment. Similarly, addition of 0.06 t/ha (13.3%) in protein yield in grains was obtained with DS treatment compared with CS (0.45 t/ha). This might be owing to the fact that, DS treatment after harvesting of *toria* facilitated advance sowing of wheat, while delayed under the CS system resulting in reduction in yield and quality. The observations showed that sowing of wheat crop was 15 days early in DS compared with CS treatment after harvesting of *toria*. Singh *et al*. (2013) reported that, pre-sowing irrigation before harvesting of pigeonpea resulted in 9.7% increase in wheat yield compared with pre-sowing irrigation after harvesting of pigeonpea. Similar observations of better growth and yield of wheat were recorded under DS and irrigation soon afterward in Alluvial soil (Singh, 2020) and in vertisols (Mulvaney *et al*., 2014). Gupta *et al*. (2000) reported that sowing of wheat after optimum date (15 November) decreased the yield by 1% (32 kg/day/ha) after each day.

The number of plant/m^2, grain, stover and protein yields of wheat were maximum and significantly influenced by seeding of crop with HS as compared with CT, whereas the difference between ZT and HS was statistically at par

Table 2. Growth parameters, yield and economics of wheat as affected by time of pre-sowing irrigation and sowing methods (pooled data of 2 years)

Treatment	Day of emergence after *toria* harvesting*	Plant/m^2	Height/ plant (cm)	Tillers/ plant	Length of spike (cm)	Grains/ spike	1,000-grain wt (g)	Grain yield (t/ha)	Stover yield (t/ha)	Protein yield (t/ha) (₹/ha)	Cost of cultivation (₹/ha)	Net returns (₹/ha)	Benefit: cost ratio
Time of pre-sowing irrigation													
CS	24	198	77.05	5.56	7.41	56.87	38.1	3.75	4.67	0.45	23,468	45,468	1.9
DS	09	209	80.51	5.91	7.84	58.79	40.3	4.22	5.11	0.51	22,818	54,618	2.4
SEm±	0.5	2.6	0.86	0.08	0.13	0.58	0.61	0.03	0.04	0.01	395	869	0.04
CD (P=0.05)	1.5	7.7	2.49	0.24	0.40	1.70	1.9	0.11	0.17	0.03	NS	2,594	0.1
Sowing method													
CT	18	194	77.62	5.54	7.47	57.40	38.9	3.87	4.64	0.46	25,035	45,766	1.8
ZT	16	206	79.10	5.42	7.69	57.69	39.4	3.96	4.81	0.48	21,045	51,653	2.4
HS	16	211	79.31	5.58	7.72	58.40	40.1	4.12	5.03	0.49	21,775	53,949	2.5
SEm±	0.3	1.7	0.63	0.06	0.09	0.41	0.43	0.02	0.03	0.01	275	601	0.03
CD (P=0.05)	1.0	5.3	NS	NS	NS	NS	NS	0.07	0.10	0.02	832	1815	0.1

*Total duration of emergence of wheat after harvest of *toria;* CS, sowing of crop after pre-irrigation; DS, dry sowing and irrigation for germination; CT, conventional tillage; ZT, zero tillage; HS, happy seeder

Minimum support price of wheat grain ₹14,000/t and 14,500/t, while stover rate in local market @ ₹3,250/t and 3,500/t during 2013–14 and 2014–15 respectively

(Table 2). The grain and stover yields were maximum and significantly higher with HS than with ZT and CT. It may be attributed to a significantly higher number of plant/m^{2}as compared with CT. The significantly higher number of plant/m^2 (211) and protein yield of grains (0.49 t/ha) were recorded with HS, followed by ZT as compared with CT. Under ZT and HS treatments, the emergence of wheat plants was 2 days earlier and a better germination was recorded compared with CT treatment after harvesting of *toria,* because seed placement was done 2 to 3 cm below the surface by narrow width inverted T type of tines. Under CT, the placing of seed in moist conditions below 4 to 5 cm of wheat seed was done by single box seed drill having wide tines (3 cm). As per observations the surface soil-moisture situation was more favourable in HS treatment compared with ZT and CT, resulting in better plant population and early rapid growth of wheat seedling. Among tillage, the seeding of wheat with HS had provided additional 0.25 t/ha (6.5%) grain and 0.39 t/ha (8.4%) stover yield as compared with CT. The research studies indicated that disturbing the soil too much through tillage operations may be avoided to obtain good wheat yield grown after maize (Sharma *et al*., 2011), pigeonpea (Singh *et al*., 2013) and rice (Singh *et al*., 2014), greengram and pearl millet (Singh *et al*., 2019), clusterbean (Singh, 2020).

Economics

The treatment of DS significantly improved the net returns (NR) and benefit: cost (B : C) ratio compared with CS (Table 2). The maximum NR and B : C ratio were ₹54,618/ha and 2.4 recorded with DS, while the minimum were ₹45,468/ha and 1.9 with CS treatment, respectively. The NR under DS of wheat were significantly higher than CS treatment owing to saving of cultivation cost and higher yield gains.

The data of economics of sowing methods revealed a significantly higher cost of production in CT as compared to ZT and HS treatments. The ZT saved ₹3,990/ha, followed by HS ₹3,260/ha compared with the total cost of production ₹25,035/ha in CT treatment. The reduced expenditure on tillage and higher yield resulted in significantly higher additional NR from wheat crop with HS and ZT treatments (₹8,183/ha and ₹5,887/ha respectively) as compared to NR ₹45,766/ha with CT. The maximum B : C ratio was observed in HS (2.5), followed by ZT (2.4) and least with CT (1.8) treatment. The lowest net income and B : C ratio with CT treatment were owing to the higher cost of cultivation and low yield of wheat crop. These results confirm the findings of in wheat crop Gupta *et al.* (2007) and Singh *et al*. (2020).

Energy indices

The DS method of wheat after *toria* harvesting required significantly lower (13.6%) energy input and specific energy than CS treatment (Table 3). Significantly higher net energy output, energy-use efficiency and energy productivity of 109 ×10^{3}MJ/ha, 7.84 and 0.263 kg grain/MJ/ha, respectively, were obtained with DS as compared 96 ×10^3 MJ/ha, 6.78 and 0.224 kg grain MJ/ha with CS treatment. The increase in net output, use efficiency and productivity of the energy of wheat crop was due to its higher productivity using less energy in treatment DS.

Under sowing methods, significantly higher energy input was recorded under CT (17.8 × 10^{3}MJ/ha) than with ZT (15.6 × 10^{3}MJ/ha) and HS (15.7 × 10^{3}MJ/ha) treatments (Table 3). The saving of energy input for production

Table 3. Energy indices and water productivity as affected by the time of pre-sowing irrigation and sowing methods of wheat (pooled data of 2 years)

Treatment	Energy input (×10^{3}MJ/ha)	Net energy output (×10^{3}MJ/ha)	Energy-use efficiency	Energy productivity (kg grain/MJ/ha)	Specific energy (MJ/kg)	Total water use (m^3/ha)	Water productivity (kg grain/m)
Time of pre-sowing irrigation							
CS	16.7	96	6.78	0.224	1.99	3832	0.98
DS	16.1	109	7.84	0.263	1.72	3549	1.18
SEm±	0.1	1	0.03	0.002	0.02	76	0.10
CD (P=0.05)	0.3	3	0.09	0.007	0.06	229	0.29
Sowing methods							
CT	17.8	97	6.44	0.217	2.10	3893	0.99
ZT	15.5	103	7.58	0.254	1.78	3592	1.10
HS	15.6	108	7.84	0.262	1.72	3586	1.15
S Em±	0.1	0.9	0.02	0.002	0.01	51	0.07
CD (P=0.05)	0.2	2.6	0.06	0.005	0.03	154	0.22

CS, Sowing of crop after pre-irrigation; DS, dry sowing and irrigation for germination; CT, conventional tillage; ZT, zero tillage; HS, happy seeder of wheat with ZT and HS were 12.4 and 11.8% as compared with CT treatment. Also, the highest energy output (108 10^3MJ/ha), energy-use efficiency (7.84), and energy productivity (0.262 kg grain/MJ/ha) were recorded in HS followed by ZT and CT treatments. It might be due to lower energy input and higher yield of wheat with HS and ZT treatments. Similar findings were recorded in wheat crops after harvesting of pigeonpea (Singh *et al.,* 2013) and cluster bean (Singh, 2020).

Water productivity (WP)

The TWU of wheat crop was significantly higher under CS than DS treatment (Table 3). The saving of irrigation water was 7.4% with DS method as compared to CS method of wheat. The WP was significantly higher under DS treatment (1.18 kg grain/m^3 water) as compared to CS (0.98 kg grain/m^3 water). This might be owing to DS just after harvesting of *toria* and irrigation for germination improved the yield of wheat by facilitating advance sowing and using less TWU.

The TWU with wheat crop varied from 3,586 to 3,893 m^3 water/ha under different sowing methods (Table 3), and it was significantly higher in CT (3,893 m^3) as compared with ZT (3,592 m^3) and HS (3586 m^3) treatments. No significant difference of TWU was observed between ZT and HS treatment. Overall, TWU saving with ZT and HS practice was 7.7 and 7.9% as compared with CT treatment. The maximum WP was with HS (1.15 kg grain /m^3) followed by ZT (1.10 kg grain/m^3) and minimum with CT (0.99 kg grain/m^3) treatment. The higher WP with HS and ZT methods could be attributed to higher yield with less water use as compared with CT method. Singh *et al*. (2013) also reported that, ZT improved WP of wheat after the harvesting of pigeonpea. Similarly, Singh (2020) equally observed that ZT improved WUE of wheat crop after harvesting of clusterbean.

Soil properties

Soil properties, *viz. p*H, electrical conductivity (EC), organic carbon (OC), bulk density (BD) and infiltration rate (IR) were not significantly influenced with time of pre-irrigation after two years of experimentation (Table 4). The organic carbon after harvesting of wheat increased under HS as compared to other methods of sowing (ZT and CT). The maximum OC (3.30 g/kg) in HS treatment was recorded followed by ZT (3.25 g/kg) and CT (3.24 g/kg). Continuous tillage operations degrad soil OC, which ultimately reduced soil fertility and structural stability. Singh *et al.* (2020) reported that ZT practice enhanced OC by providing better conditions in terms of soil moisture, prolong crop duration owing to advancement of sowing and temperature for higher biomass production and reduction oxidation. Singh (2020) also reported significantly higher soil OC with ZT after harvest of wheat grown after clusterbean as compared with CT treatment. Significantly lower BD of surface soil (0 to 15 cm depth) was recorded with HS and ZT as compared with CT treatment. Sowing methods did not significantly alter the BD of subsoil (15 to 30 cm). The BD was slightly higher in subsurface (15 to 30 cm) depth as compared to surface (0 to 15 cm) soil depth. The IR after harvesting of the wheat crop was significantly higher under HS (6.6 mm/h) and ZT (5.6 mm/h) treatments as compared with CT (5.2 mm/h), whereas IR was found at par with HS and ZT treatments. The higher IR under ZT treatments might be due to greater continuity of soil pores and undisturbed dead root channels. Singh (2020) reported that, tillage disrupts pore continuity and decreases water infiltration.

Under intensive cropping system, the sowing of wheat often gets delayed after harvesting of *toria* due to pre-

Table 4. Soil properties after harvest of the second wheat crop as affected by the time of pre-sowing irrigation and sowing methods

Treatment	×*p*H	EC (dS/m)	OC (g/kg)	Bulk Density (Mg/m^3) 0–15cm	Bulk Density (Mg/m^3) 15–30 cm	I R (mm/h)
Time of pre-sowing irrigation						
CS	7.73	0.40	3.27	1.52	1.60	5.7
DS	7.79	0.41	3.26	1.51	1.60	5.8
SEm±	0.04	0.015	0.02	0.02	0.012	0.03
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Sowing method						
CT	7.76	0.39	3.24	1.56	1.60	5.2
ZT	7.78	0.42	3.25	1.50	1.61	5.6
HS	7.73	0.41	3.30	1.49	1.59	6.6
SEm±	0.03	0.009	0.02	0.01	0.008	0.02
CD (P=0.05)	NS	NS	NS	0.03	NS	0.06

CS, Sowing of crop after pre-irrigation; DS, dry sowing and irrigation for germination; CT, conventional tillage; ZT, zero tillage; HS, happy seeder, EC, electrical conductivity, OC, organic carbon; IR, infiltration rate sowing irrigation and intensive tillage operations for seed-bed preparations followed by farmers, resulting in low yield, quality and benefits in spite of using high inputs and energy. Results showed that, dry sowing of wheat with happy seeder and irrigation for germination positively influenced the growth parameters, yield, quality, economic benefits, energy outcomes, water productivity and soil properties, followed by zero-tillage sowing practice compared with conventional tillage method. Thus, dry sowing of wheat with happy seeder proved promising, while zero tillage remains the second-best option for sustainable beneficial intensive cropping system in Central India.

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