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Effect of time of pre-irrigation and tillage practices on wheat (*Triticum aestivum*) under pigeonpea (*Cajanus cajan*) - wheat cropping sequence

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ABSTRACT

A field experiment on wheat (*Triticum aestivum* L.) under pigeonpea (*Cajanus cajan* (L.) Millsp) wheat cropping sequence was carried out in *rabi* season of 2010-11 and 2011-12 to evaluate time of pre-irrigation such as before and after harvest of pigeonpea and different tillage practices, viz. zero tillage (ZT), minimum tillage (MT), conventional tillage (CT) sowing methods on growth, yield, economics and soil properties on sandy loam soil. Pre-irrigation before harvest of pigeonpea significantly influenced the growth parameters, yield, net profit, benefit cost (B : C) ratio, energy input, output, use-efficiency and energy productivity as compared to pre-irrigation after harvest of pigeonpea. Similarly, growth parameters, yield, net return, B:C ratio, energy output, use-efficiency and productivity of energy were significantly influenced by ZT sowing method compared with CT, whereas non-significant difference in growth parameters and yield between MT and CT treatment was observed. Maximum energy input was noticed in CT followed by MT and ZT. The increase in grain and straw yields by 5.32% and 5.94%, respectively, was observed with ZT over CT. Maximum cost of production was observed with CT as compared to MT and ZT. With ZT the maximum of ₹ 3 760/ha was saved followed by MT (₹ 1 490/ha) as compared to CT. Total water-used by wheat was significantly higher in CT (43.57 cm) as compared to ZT (40.66 cm), whereas maximum water use efficiency with ZT was 108.1 kg followed by CT (96.9 kg) and MT (95.2 kg). The water use efficiency for CT and MT was at par. Pre-irrigation before harvesting of pigeonpea significantly improved water-use efficiency (105.1 kg) as compared to pre-irrigation after harvest of pigeonpea (95.0 kg). After harvest of wheat, organic carbon and infiltration rate were significantly influenced under ZT followed by MT and CT. Lowest bulk density was noticed in surface soil (0 to 15 cm depth) with ZT as compared to other methods of tillage, while there was slight increase in bulk density of sub-surface soil (15-30 cm depth) in all the treatments..

Key words: Energy, Growth, Pre-irrigation, Soil properties, Tillage, Water use, Wheat, Yield

Pigeonpea [*Cajanus cajan* (L.) Millsp] - wheat (*Triticum aestivum* L.) is an efficient, potential and sustainable cropping system in north plains. Area under long duration varieties of pigeonpea which dominated in central India is shrinking as compared to previous years. This reduction of area is due to the fact that long duration pigeonpea takes 220 to 250 days for maturity, and consequently only a single crop could be grown in a year. Further, several times long duration crop suffers from severe frost and diseases like wilt and sterility mosaic. Short duration sequential cropping has emerged due to development of short-duration photo- and thermo-insensitive cultivars and expansion of irrigation facilities (Ahlawat *et al*. 2005). After harvesting of short duration pigeonpea, wheat sowing is delayed due to 5 to 8 tillage operations after pre-irrigation. Timely planting of wheat is crucial as yield reductions of 1 – 1.5% per day occur for each day's delay after the optimum sowing date of wheat (Hobbs and Morris 1996). In addition to this, land preparation requires high input of energy which increased cost of cultivation of wheat crop. Delayed sowing of wheat required more inputs like seed, nutrient, irrigation etc. and crop was also affected adversely by terminal heat. To overcome above problems, conservation tillage and management of pre-irrigation is the only way to mitigate the adverse effects on wheat crop in pigeonpea – wheat cropping sequence. Several recommendations of conservation tillage on paddy and maize crop based cropping system have been made (Gupta *et al*. 2000 and Sharma *et al.* 2011). However, information is lacking for pigeonpea based cropping system. Keeping these points in view, a study was conducted to investigate the effect of tillage practices and time of pre-irrigation on wheat under pigeonpea - wheat crop sequence.

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MATERIALS AND METHODS

On farm trails were conducted using five locations in alluvial soils of Morena district in Madhya Pradesh for two years (2010 – 2012). The study area lies between 23° 15' to 26° 45' N – latitude and 70° 30' E – longitude with a altitude ranging from 150 to 240 m. District Morena is categorized under Gird Agro-climatic zone. The climate of this zone is characterized as semi-arid and extremely hot during May-June. The treatment consisted of time of pre-irrigation, viz. P_1-before harvest of pigeonpea (10th November), P_2 after harvesting of pigeonpea (18th November) in main plot and tillage practices in sub plot such as zero tillage sowing method (ZT), sowing of wheat crop under minimum tillage after two ploughing by cultivator (MT) and conventional tillage sowing after 6 ploughing by cultivator (CT). Trails were laid out in split plot design with 5 replications. The soil of the experimental site was sandy loam in texture, bulk density (0-15cm) ranging from 1.49 to 1.52 Mg/m^3, infiltration rate from 7 to 11 mm/hr and effective soil depth 110 to 130cm. Other soil characteristics include deficient in organic carbon, available nitrogen, low to medium in phosphorus, sulphur, zinc and high in available potassium (Table 1). The recommended dose of fertilizers for this zone was 100 kg N, 60 kg P_2O_5, 40 kg S and 20 kg $ZnSO_4$/ha for wheat. Full dose of P, S, Zn and half dose of N was applied as basal application in wheat crop and remaining N at panicle initiation stage. The sources of N, P and S were urea, dia-ammonium phosphate and elemental sulphur, respectively. A variety of wheat MP 4010 was sown after harvest of pigeonpea and package of practices were followed as per recommendation. Total five recommended irrigations were applied at stages of CRI, tillering, flowering, milking and grain development. Annual rainfall received 644.4 mm (2010-11) and 851.2 mm (2011-12) was mostly concentrated in the months of July and August. During cropping period of wheat, 27.7 and 5.8 mm rainfall was received during first and second year, respectively.

After harvest of wheat crop, grain and straw yields were recorded. Soil samples were collected from 0 to 15 cm depth before sowing and at harvest of crop from three 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. Organic carbon was analyzed by Walkley and Black method, 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. Bulk density (0-15 and 15-30 cm), infiltration rate after saturation of soil was measured after harvest of crop using a double-ring infiltrometer. Economics of treatments was also computed taking into account the prevailing market prices for inputs and outputs. Soil water content was measured gravimetrically in 0–180 cm soil profile at 15 cm increments for first two layers, and at 30 cm subsequently. Consumptive water use and water-use efficiency was calculated as suggested by Singh *et al.* (1999). Energy input and output were calculated by using the procedure described by Devasenapathy *et al.* (2009). Energy-use efficiency and energy productivity (g/MJ/ha) were calculated using the formula reported by Gupta *et al.* (2007).

RESULTS AND DISCUSSION

Growth, yield and economics

Growth parameters (plant height, tillers/plant, spike length, number of grains/spike, and 1000-grainweight), grain and straw yields of wheat were significantly higher under pre-irrigation before harvesting of pigeonpea crop as compared to pre-irrigation after harvesting of pigeonpea (Table 2). The highest plant height (79.58 cm), tillers (5.56/plant), spike length (7.83 cm), number of grains/spike (68.49), 1000-grain weight (40.95 g) were recorded with preirrigation before harvesting of pigeonpea. Additional 3.93 q/ha grain and 4.93 q/ha straw yield was obtained with pre-irrigation before harvest of pigeonpea as compared to pre-irrigation after harvest. This might be due to the fact that pre-irrigation before harvest of pigeonpea facilitated advance sowing of wheat. This confirmed the observation by Hobbs and Morris (1996) that yield was reduced each day after optimum date of sowing of wheat.

Plant height, tillers/plant, spike length, number of grains/spike, 1000-grain weight and yield were maximum and significantly influenced by zero tillage (ZT) in comparison to minimum tillage (MT) and conventional tillage (CT), but the difference between MT and CT was not significant (Table 2). Significantly higher values of plant height (79.72 cm), tillers (5.59/plant), spike length (7.94 cm), grains/spike

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

Locations	Texture	pH	EC (dS/m)	OC (g/kg)	Bulk density (Mg/m^3)	IR (mm/hr)	Available nutrients N (kg/ha)	P (kg/ha)	K (kg/ha)	S (kg/ha)	Zn (mg/kg)
Dhamkan	Sandy loam	7.7	0.39	2.7	1.59	05	145	9.4	305	8.5	0.60
Arela	Sandy loam	7.9	0.40	3.2	1.60	05	168	9.9	290	9.8	0.45
Mundrabaja	Sandy laom	7.6	0.28	4.1	1.57	06	174	10.7	318	11.8	0.52
Nidhan	Sandy laom	8.1	0.53	2.9	1.51	04	151	9.5	360	10.9	0.49
Jigani	Sandy laom	7.6	0.31	3.4	1.49	06	160	11.4	299	12.5	0.71

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

Treatment	Height/ plant (cm)	No. of tillers/ plant	Length of spike (cm)	No. of grains/ spike	1000-grain wt (g)	Grain yield (q/ha)	Stover yield (q/ha)	Cost of production (₹/ha)	Net return (₹/ha)	B:C ratio
Time of pre-irrigation										
P_1	79.58	5.56	7.83	68. 49	40-95	44.51	53.60	24013	47861	3.01
P_2	78.81	5.46	7.73	67.17	39-54	40.58	48.67	23757	41636	2.76
CD (P=0.05)	0.77	0.09	0.25	1.30	0.13	1.12	1.20	NS	1594	0.05
Tillage practices										
CT	79.16	5.54	7.72	67.50	39.99	41.91	50.31	25635	42312	2.65
MT	78.71	5.40	7.69	67.39	39.97	41.59	49.81	24145	42720	2.77
ZT	79.72	5.59	7.94	68.60	40.79	44.14	53.30	21875	49214	3.24
CD (P=0.05)	0.53	0.14	0.23	0.74	0.07	0.69	1.15	399	569	0.09

P_1-Pre-irrigation before harvesting of pigeonpea, P_2-pre-irrigation after harvesting of pigeonpea, CT-conventional tillage, MT-minimum tillage, ZT-zero tillage, B:C ratio- benefit cost ratio

(68.60) and 1000-grain weight (40.79 g) were recorded under ZT followed by CT and MT. Among tillage, sowing of wheat by ZT provided additional 2.23 q/ha grain and 2.99 q/ha straw yield as compared with CT. Prasad *et al.* (2006) reported that disturbing the soil too much through tillage operations is not actually required to obtain good crop yield.

Pre-irrigation before harvest of pigeonpea significantly improved net profit and B:C ratio in comparison with pre-irrigaion after harvest (Table 2). The maximum values of net profit and B:C ratio were ₹ 47 861/ha and 3.01, respectively, with pre-irrigation before harvest of pigeonpea, while minimum values of ₹ 41 637/ha and 2.76, respectively, with pre-irrigation after harvest of pigeonpea. The data on economics of tillage revealed a significantly higher cost of production in CT compared to MT and ZT. ZT saved ₹ 3 760/ha followed by MT ₹ 2 270/ha compared with cost of production (₹ 25 635/ha) in CT treatment. The reduced expenditure on tillage and higher yield provided significantly higher additional net profit from wheat crop (₹ 6 902/ha) with ZT as compared to CT (net return ₹ 42 313/ha). Maximum value of B:C ratio was observed in ZT followed by MT and CT. The lowest net income and B:C ratio with CT was owing to the highest cost of cultivation and low yield of wheat crop.

Energetics, water use and use-efficiency

Significantly higher values of energy input, output, energy use-efficiency and energy productivity obtained were 16.0 610^3 MJ/ha, 132.2 10^3 MJ/ha, 8.26 and 277. 81 g/MJ/ha, respectively, with pre-irrigation before harvest of pigeonpea treatment, as compared to 16.03 10^3 MJ/ha, 120.5 10^3 MJ/ha, 7.54 and 253.86 g/MJ/ha, respectively, with pre-irrigation after harvest of pigeonpea treatment in wheat crop (Table 3). The increase in energy output, energy use-efficiency and energy productivity of wheat crop was due to its higher productivity in the treatment of pre-irrigation before harvest of pigeonpea. Under different tillage practices, significantly higher energy input was recorded under CT (16.88 10^3MJ/ha) in comparison to ZT (15.24 10^3MJ/ha) sowing method (Table 3). The saving of energy consumption was 10.76% in ZT in comparison with CT practice of sowing. Also, the highest energy output, use-efficiency and productivity were

Table 3 Energetics, water use and water use efficiency affected by time of pre-irrigation and tillage practices on wheat (pooled data of 2 years)

Treatment	Energy input (× 10^3 MJ/ha)	Energy output (× 10^3 MJ/ha)	Energy use-efficiency	Energy productivity (g/MJ/ha)	Water use (cm)	Water use efficiency (kg grain/cm/ha)
Time of pre-irrigation						
P_1	16.06	132.2	8.26	277.81	42.43	105.1
P_2	16.03	120.5	7.54	253.86	42.63	95.0
CD (P = 0.05)	0.02	1.7	0.09	6.71	NS	2.92
Tillage practices						
CT	16.88	125.8	7.49	249.95	43.57	96.9
MT	16.01	123.3	7.69	259.29	43.36	95.2
ZT	15.24	129.9	8.52	288.26	40.66	108.1
CD (P = 0.05)	0.02	1.8	0.12	4.42	0.92	3.03

P_1-Pre-irrigation before harvesting of pigeonpea crop, P_2-pre-irrigation afterharvesting of pigeonpea, CT-conventional tillage, MT-minimum tillage, ZT-zero tillage

Table 4. Physico-chemical properties of soil after harvest of wheat affected by time of pre-irrigationand tillage practices on wheat (pooled of 2 years)

Treatment	pH	EC (dS/m)	OC (g/kg)	Bulk Density (Mg/m³)		I R(mm/hr)
				0-15cm	15-30cm	
Time of pre-irrigation						
P_1	7.73	0.40	3. 27	1.52	1.60	5.77
P_2	7.79	0.41	3.26	1.51	1.60	5.80
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Tillage practices						
CT	7.76	0.39	3.24	1.56	1.60	5.36
MT	7.78	0.42	3.25	1.50	1.61	5.38
ZT	7.73	0.41	3.30	1.49	1.59	6.60
CD(P=0.05)	NS	NS	0.04	0.01	NS	0.07

P_1-Pre-irrigation before harvesting of pigeonpea crop, P_2-pre-irrigation after harvesting of pigeonpea, CT-conventional tillage, MT-minimum tillage, ZT-zero tillage, EC-electrical conductivity, OC-organic carbon IR- infiltration rate

recorded in ZT. It might be due to lower energy input and higher yield with ZT. Gupta *et al.* (2007) also reported similar results on wheat crop in rice – wheat cropping system.

The total water-use by wheat crop varied from 40.66 to 43.57 cm under different tillage practices (Table 3), and it was significantly higher in CT (43.57 cm) than ZT (40.66 cm). No significant difference was observed between MT and CT. Overall irrigation water saving with ZT practice was 7.16% as compared with CT. Maximum water use efficiency was 108.1 kg grain/cm/ha in ZT followed by CT (96.9 kg grain/cm/ha) and MT (95.2 kg grain/cm/ha). The higher water use efficiency in ZT could be attributed to higher yield with least water use by the crop. Gupta *et al.* (2000) also reported that zero tillage improved water use efficiency of wheat crop. Non-significant difference was observed in water use between times of pre-irrigation, whereas a significant difference was observed in water use efficiency. Higher water-use efficiency (105.1 kg grain/cm/ha) was obtained with treatment of pre-irrigation before harvesting of pigeonpea as compared with pre-irrigation after harvest of pigeonpea (95.0 kg grain/cm/ha).This might be due to pre-irrigation before harvesting of pigeonpea improving the yield of wheat by facilitating timely sowing of wheat.

Physico-chemical properties of soil

Soil pH and electrical conductivity were not significantly influenced by time of pre-irrigation and tillage practices after two years of experimentation (Table 4).The organic carbon after harvest of wheat was significantly increased under ZT as compared to other methods of tillage (CT and MT). Maximum values of organic carbon in ZT plot was 3.30 g/kg followed by MT (3.25 g/kg) and CT (3.24 g/kg). Continuous tillage operations degraded soil organic matter, which ultimately reduced soil fertility and structural stability. Mishra *et al.* (2010) also reported significantly higher soil organic carbon with no-tillage when compared with conventional tillage in maize grown soil. Significantly lower bulk density of surface soil (0 to 15cm depth) was noticed with CT than ZT. Tillage practices did not significantly alter the bulk density of sub-soil (15 to 30 cm). Bulk density was slightly higher in 15 to 30 cm soil depth as compared to 0 to 15cm depth. Non-significant difference was observed in bulk density in both the surface and sub-surface soil with time of pre-irrigation. The infiltration rate after harvest of wheat crop was significantly higher under ZT (6.60 mm/hr) as compared with CT (5.36 mm/hr), whereas infiltration rates were at par with both CT and MT. The higher infiltration rate under zero tillage might be due to greater continuity of soil pores and undisturbed dead root channels. Infiltration rate at harvest of wheat crop was not significantly influenced by time of pre-irrigation after two year of experimentation.

It is concluded that adoption of zero tillage practice of sowing after pre-irrigation before harvesting of short duration variety of pigeonpea for sowing of wheat crop in pigeonpea-wheat cropping sequence produced significantly higher yield and profit, saved energy and resources under the soil and climatic conditions of Gird zone of Madhya Pradesh.

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