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Pre-irrigation and seeding of wheat (*Triticum aestivum*) after clusterbean on yield, water productivity and soil properties

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ABSTRACT

On farm research was conducted during winter (*rabi*) of 2014-17 to study the effect of dry seeding (DS) of wheat (*Triticum aestivum* L.) for early establishment after harvest of clusterbean and irrigation for germination compared with conventional practice of pre-irrigation (PI) for seeding in three tillage practices, viz. conventional (CT), minimum (MT), zero-till (ZT). Pooled results indicated that the seeding of wheat with ZT method in DS conditions significantly influenced the growth parameters; yield, economic benefits, energy output and water productivity (WP) over conventional practices. The grain yield of wheat was increased by 5.1-11.6% with DS and 5.0-10.7% with ZT over conventional practices, respectively. The significantly higher production cost was recorded with CT compared to ZT. Out of total production cost, higher expenditure (22.2%) on tillage and seeding with CT, whereas with MT and ZT was 11.5% and 3.7%, respectively. The significantly higher energy input and total water use (TWU) was required with CT over ZT. The additional 263 m^3/ha TWU was saved and WP increased by 17.5% with DS, while 234 m^3/ha TWU was saved and WP increased by 16.4% with ZT over conventional practices, respectively. After harvest of third wheat crop, organic carbon, infiltration rate, available N, P, K and Zn were significantly increased, whereas bulk density was lowest with ZT over CT. The study reveals that improved yield, economic benefits, WP, soil physicochemical properties, saved energy and resources with DS of wheat after clusterbean harvest with ZT seeding and irrigation for germination in late sown conditions.

Key words: Irrigation timing, Seeding, Soil properties, Water productivity

Clusterbean (*Cyamopsis tetragonoloba* Taub.) – wheat (*Triticum aestivum* L.) cropping sequence is grown in arid and semi-arid regions of India. India has an area 5.6 million ha of clusterbean during 2013-14 and contributes to 75-82% of total production of world (Kumar and Solanki 2013). Clusterbean is a deep rooted leguminous crop having diversified uses. In general seeding of clusterbean after first rain of *kharif* takes about 125 to 170 days for maturity depending upon cultivars and rainfall duration. The seeding of wheat is delayed due to harvesting of clusterbean from last week of November to whole month of December. The seeding of wheat is further delayed due to seeding of crop after 5 to 8 tillage operations performed after pre-irrigation for seed bed preparation (Singh *et al*. 2019). The extreme winter in month of December field takes 10-15 days after pre-irrigation to come up condition for seeding. Timely planting of wheat is crucial as yield reductions from 1-1.5% for each day's delay after the optimum seeding date of wheat (Hobbs and Moris 1996). In additions delayed seeding of wheat requires more inputs and adversely affected by terminal heat and lodging due to increase of wind speed at reproductive stage. The wind speed increases with increasing temperature in India (Singh *et al*. 2019).

Conservation tillage involves soil management practices that minimize the disruption of the soil structure, significantly saves the time of seed bed preparation, increases soil organic matter (OM) and reduces operation costs (Singh *et al*. 2013). Similarly, reduced tillage systems required lower operation costs and gave greater returns over conventional tillage (Singh *et al.* 2019). Scientific studies revealed that conservation tillage provided the best opportunity for improving soil quality and enhancing crop productivity (Singh *et al*. 2013, Singh *et al*. 2019). Under late conditions management of pre-irrigation timing and conservation tillage practices are the only ways to mitigate the adverse effects. Keeping above points in view, a study was conducted to investigate the pre-irrigation timing and seeding effects on wheat grown after harvest of clusterbean in semi-arid climatic conditions.

MATERIALS AND METHODS

A field experiment was conducted during *rabi* 2014-17 at Hadbansi village of Morena district (Madhya Pradesh). The coordinates of study area are 26.4497° N, 77.8882° E at an altitude of 189 m amsl in the Gird Agro-climatic zone.

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The climate of study site was semi-arid, extremely cold during December-January (-1.0°C minimum temperature) and hot during May-June (49°C minimum temperature). The major climatic vulnerabilities for wheat crop of this zone were drought, abnormal winter rains and terminal heat. Average annual rainfall of experimental area is 701 mm, mostly concentrated in the months of July and August. The annual total rainfall were 873, 795 and 566 mm, whereas during wheat period, winter rains were 126, 3 and 6 mm received during 2014-15, 2015-16 and 2016-17, respectively. The rainfall during reproductive wheat period was 72 mm recorded during 2014-15.

Soil samples (0-15 cm) were collected from selected field in the beginning of the experiment and after harvest of 3rd wheat crop for determining soil properties. The soil of experimental site was sandy loam in texture classified under Entisols, bulk density (BD) ranging from 1.49 to 1.51 Mg/m^3, infiltration rate (IR) from 7 to 9 mm/hr, neutral in reaction (*p*H 7.73), low in organic carbon (4.38 g/kg), low in available NPS (170:9.7:8.9 kg/ha) and DTPA-Zn (0.53 mg/kg). The available K (279 kg/ha) was medium, while Cu, Fe and Mn micronutrients content were above their critical limits of deficiency.

The treatments were consisted of two irrigation timing for wheat establishment, viz. dry seeding (DS) just after harvest of clusterbean and irrigation for germination and pre-irrigation (PI) after harvest of clusterbean and three tillage and seeding methods- conventional tillage (CT), minimum tillage (MT) and zero tillage (ZT). The practices were followed in CT (2 ploughings with disc harrow + 2 passes of cultivators and planking in last ploughing). In CT, wheat was seeded by single box seed drill in two pass e.g. one for drilling of fertilizer and one for seeding. In MT crop established after 2 ploughings by cultivator and planking in last ploughing followed by seeding with seed cum fertilizer drill. In ZT, seeds were directly drilled with fertilizers using zero till seed cum fertilizer drill with inverted 'T' tynes. The row spacing of wheat was maintained at 20 cm in all treatments. The plot size of each treatment was 250 m^2. The experiment had six treatments and three replications in randomized block design.

After harvest of clusterbean the seeding of wheat variety GW-366 @ 120 kg/ha in first week of December during 2014 and 2016, while last week of November during 2015 in DS treatment. Like-wise in PI treatments in third week of December during 2014 and 2016, while second week of December in 2015, respectively. The seed was treated with each of carbendazim 2 g + *Azotobactor* 10 g + PSB 10 g/kg. The recommended dose of fertilizers was 120 kg N, 60 kg P_2O_5, 40 kg K_2O and 20 kg $ZnSO_4$/ha for wheat. Full dose of P, K, Zn and half dose of N was applied as basal and remaining N at panicle initiation stage. The sources of N, P, K and Zn were urea, dia-ammonium phosphate, muriate of potash and zinc sulphate, respectively. Weeds were managed with use of 25 g sulfosulfuron + 20 g metsulfuron/ha.

The energy equivalent of all inputs such as use of machinery, labour, seed, irrigation, chemical and bio-fertilizers, herbicides, pesticides and operations of harvesting and threshing, etc. used for crop production were worked out. Similarly, the energy equivalents of input and outputs were calculated as suggested by Devasenapathy *et al.* (2009). Energy input and output were calculated formulas as adopted by Singh *et al*. (2019).

Soil samples were collected from 0-15 cm depth before seeding and after harvest of 3rd wheat from three locations within a plot. The collected soil samples were mixed thoroughly, air-dried, crushed and passed through a 2-mm sieve and stored in plastic jars before analysis. The physicochemical properties such as BD of 0-15 and 15-30 cm, and IR after saturation of soil, electrical conductivity (EC) and *p*H were determined in 1:2 soil water suspensions, organic carbon, available N by Kjeltec-II auto analyzer, Olsen P and K by NH_4OAc and micronutrients by DTPA extraction (Page *et al*. 1982).

All the research plots were irrigated separately with boarder strip method and amount of irrigation water measured with water meter. The six irrigations included pre-irrigation were applied during 2015-16 and 2016-17, while only four irrigations during 2014-15 due to winter rains. The volume of irrigation water was measured with the help of water meter. Soil water content was measured gravimetrically in 0-150 cm soil profile at 15 cm increments for first two layers, and at 30 cm subsequently. Soil moisture (%) was determined thermo-gravimetrically. The TWU was calculated as summed of effective rainfall, amount of water (input water) applied plus change in soil water storage (0-150 cm) between seeding and harvesting of each season. The WP was calculated as:

$$\text{Water productivity (kg grain/m}^3\text{)} = \text{Grain yield of wheat (kg/ha)/Total water use (m}^3\text{/ha)}.$$

The total cost of cultivation of wheat was calculated on the basis of different operations performed and inputs used for raising the crop. Economics of treatments was computed taking all operations for wheat into account and the prevailing market prices for inputs. Gross returns were calculated by multiplying grain yield with minimum support price and the stover yield with prevailing market price. Net returns (NR) were calculated as:

$$\text{NR} = \text{Gross return} - \text{Total cost of production}.$$

RESULTS AND DISCUSSION

Growth and yield: Growth and yield components, viz. plant height, tillers/plant, spike length, number of grains/spike and 1000-grain weight of wheat varied significantly with treatments of PI timing (Table 1). The significantly plant height (85.6 cm), tillers/plant (4.23), spike length (9.39 cm), number of grains/spike (47.0), 1000-grain weight (45.21 g) of wheat were recorded with DS as compared with PI treatment. The winter rains along with wind during flowering to maturity duration of wheat resulted in crop lodging during 2014-15. Among pre-irrigation timing treatment of

Table 1 Growth parameters, yield, economics, energetics and WP of wheat as affected by pre-irrigation timing and seeding methods of wheat (3 year pooled data)

Treatment	Height / plant (cm)	No. of tillers / plant	% plant lodging (2014-15)	Length of spike (cm)	No. of grains/ spike	1000-grain wt. (g)	Grain yield (t/ha)			Stover yield (t/ ha)	Cost of production (₹/ha)	Net return (₹/ha)	Energy in-put (×10^3 MJ/ha)	Energy output (×10^3 MJ/ha)	TWU (m^3 water/ ha)	WP (kg grain/m^3 water)
							2014-15	2015-16	2016-17							
Pre-irrigation timing																
PI	83.8	4.03	27	9.27	46.1	44.37	3.84	4.39	4.12	5.13	27,923	49,349	17.23	130.0	3395	1.20
DS	85.6	4.23	24	9.39	47.0	45.21	4.28	4.61	4.51	5.44	28,031	55,464	17.12	138.4	3132	1.41
CD (P=0.05)	1.1	0.19	2.7	0.07	0.7	0.97	0.15	0.13	0.18	0.08	NS	285	NS	1.6	71	0.07
Seeding methods																
CT	84.3	4.0	32	9.31	46.2	43.93	3.74	4.42	4.24	5.25	30,691	47,060	18.69	133.3	3351	1.22
MT	84.2	4.04	27	9.28	46.3	44.59	3.80	4.44	4.20	5.21	27,712	50,235	17.10	132.7	3274	1.27
ZT	85.6	4.30	18	9.41	47.1	45.87	4.14	4.64	4.50	5.40	25,518	57,256	15.72	136.6	3117	1.42
CD (P=0.05)	0.9	0.14	1.9	0.05	0.6	0.75	0.11	0.09	0.12	0.05	287	230	0.83	1.4	59	0.05

PI, Pre-irrigation before sowing; DS, Dry seeding and irrigation for germination; CT, Conventional tillage; MT, Minimum tillage; ZT, Zero tillage; TWU, Total water use; WP, Water productivity.

wheat plant significantly higher lodging was observed with PI (27%) compared with DS (24%). The grain yield was increased by 11.6% in DS in abnormal weather conditions (2014-15), while in normal season increased by 5.1 and 9.5% in DS over PI during 2015-16 and 2016-17, respectively. Similar trend of stover yield of wheat was also recorded. This might be due to the fact that DS after harvest of clusterbean facilitated 10-15 days advance seeding of wheat and less lodging effects compared with PI. Similar observations of higher growth and yield of wheat was recorded under DS and irrigated soon afterward in Vertisol (Mulvaney *et al.* 2014). Hobbs and Moris (1996) reported that seeding of wheat after optimum date reduced the yield by 1.0-1.5% with each day delay in seeding.

Significantly higher plant height (85.7 cm), tillers/ plant (4.30), spike length (9.41 cm), grains/spike (47.1) and 1000-grain weight (45.87 g) were recorded under ZT over CT and MT treatment (Table 1). The soil moisture was more favourable in ZT resulting in better plant population and early rapid growth of wheat seedling (Singh *et al*. 2013). On the other hand, winter rains along with wind at reproductive stage of crop resulted in maximum lodging of wheat plant under CT (32%) followed by MT (27%) and least with ZT (18%) during 2014-15. The grain yield was increased by 10.7% in ZT in abnormal weather conditions (winter rains) during 2014-15, while in normal weather conditions yield increased by 5.0% and 6.1% in ZT over CT during 2015-16 and 2016-17, respectively. The present study also described that the crop established with ZT method showed significantly less lodging of wheat crop in abnormal winter rains compared with other treatments of seeding methods resulting in higher wheat productivity. The research studies indicated that disturbing the soil too much through tillage operations was not actually required to obtain good crop yield of wheat grown after harvest of pigeonpea (Singh *et al*. 2013) and paddy (Singh *et al*. 2019).

Economics: The seeding of wheat crop by DS method after harvest of clusterbean significantly improved net profit as compared with PI (Table 1). The DS method of wheat gave additional net profit of ₹ 6115/ha compared with PI (₹ 49349/ha). The NR under DS of wheat was significantly higher compared with PI due to saving of cultivation cost and higher yield gains. Economic data of seeding treatments revealed significantly higher cost of production in CT compared to MT and ZT. The seeding of crop with ZT method saved ₹ 5173/ha followed by MT ₹ 2979/ha as compared with cost of production in CT. The reduced expenditure on seeding and higher yield provided significantly higher additional net profit from wheat crop with ZT (₹ 10196/ha) as compared to NR of CT. Similar findings on wheat crop after harvest of pigeonpea reported by Singh *et al.* (2013).

Production cost of various agronomical practices (Fig 1) under CT for seed bed preparation of wheat had maximum expenditure ₹ 5650/ha followed by chemical fertilizers (₹ 5360/ha), irrigation (₹ 5202/ha), harvesting of crop (₹ 4950/ha), seed (₹ 3600/ha), threshing

(₹ 3250/ha) and weed management (₹ 1400/ha), whereas least with seed treatment (₹ 225/ha). However with MT treatment, maximum expenditure was under chemical fertilizers (₹ 5360/ha), followed by harvesting of crop (₹ 5190/ha), irrigation (₹ 5180/ha), seed (₹ 3600/ha), threshing (₹ 3350/ha) and seed bed preparation (₹ 2530/ha). Regarding ZT seeding expenditure was higher only from seed treatment and least with various agronomical practices followed in wheat crop.

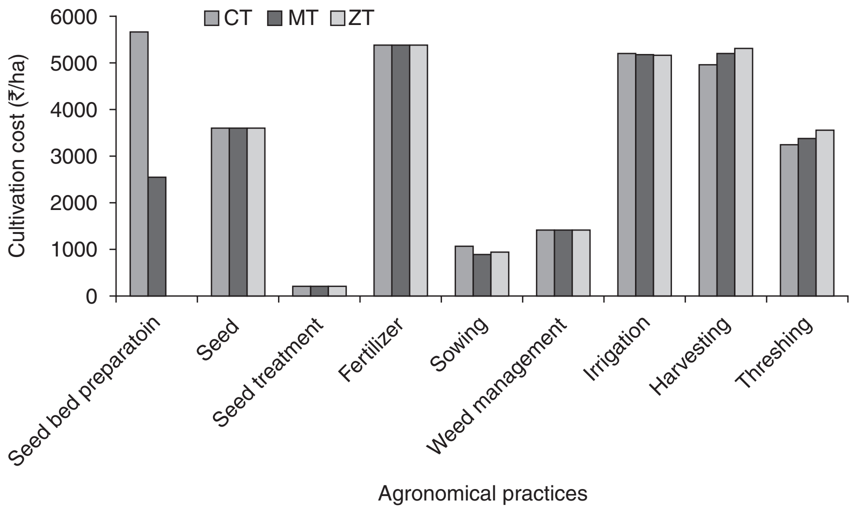

Fig 1 Cultivation cost of various agronomic practices under different seeding methods of wheat (3 year pooled data).

Energy indices: The DS method of wheat after harvest of clusterbean increased significantly energy output as compared to PI treatment (Table 1). The energy output was increased by 6.5% in case of DS as compared to PI. The increase in energy output was due to higher productivity of wheat using less energy with DS treatment.

Under seeding practices, significantly higher energy input was recorded under CT as compared to ZT. The saving of energy input was 18.9% with ZT as compared with CT (18.69 ×10^3 MJ/ha). Also, the higher energy output was recorded with ZT over CT treatment. It was due to lesser energy input required for wheat crop and higher productivity with ZT. Singh *et al*. (2019) also reported that delayed establishment of wheat after CT required more energy, while timely sown crop needed less energy and produced more energy. Similar results of wheat crop in paddy/maize/pigeonpea/pearlmillet based cropping systems were reported by Gupta *et al.* (2007), Singh *et al*. (2013) and Singh *et al*. (2019).

Water productivity: The TWU of wheat crop was significantly higher under PI as compared to DS treatment (Table 1). Saving of TWU was 7.8% with DS method as compared to PI. The WP was significantly higher under DS (15.2%) as compared to PI. The WP increased due to higher yield using less TWU under dry seeding just after harvest of clusterbean.

The TWU of wheat crop was varied from 3117 to 3351 m^3/ha under seeding methods and it was significantly higher in CT as compared with MT and ZT. Overall irrigation water saving with ZT was 7.0% as compared with CT. Singh *et al*. (2019) also observed that TWU by wheat was significantly higher under CT over ZT. Maximum WP was 1.42 kg grain/m^3 water in ZT followed by MT and CT. The higher WP in ZT could be attributed to higher yield with low amount of irrigation as compared with other seeding treatments. Similarly ZT seeding improved WP of wheat crop after harvest of paddy and pigeonpea (Gupta *et al.* 2007, Singh *et al*. 2013).

Soil physicochemical properties: Physicochemical properties of soil were not significantly affected by treatments of pre-irrigation timing after three years of experimentation. The physicochemical properties of soil, viz. OC, IR, available N, P, K and Zn were significantly influenced, whereas *p*H, BD was lowest in ZT over CT and MT (Table 2). Maximum values of OC in ZT treatment was 4.42 g/kg followed by MT and CT. Continuous tillage operations degraded soil OC, which ultimately reduced soil physicochemical properties. Shukla *et al.* (2003) reported that ZT practice enhanced OC by providing better conditions in terms of moisture; prolong crop duration due to advancement seeding and temperature for higher biomass production and reduction oxidation. Similarly, significantly higher soil OC with ZT when compared with CT in wheat grown after paddy, pearlmillet, clusterbean and pigeonpea (Singh *et al*. 2019).

Lowest BD was noticed in surface soil (0-15 cm) with ZT as compared to other methods of tillage due to decomposition of crop residues and more root masses

Table 2 Physicochemical properties of soil as affected by seeding methods after harvest of 3rd wheat crop

Seeding methods	*p*H	EC (dS/m)	OC (g/kg)	Bulk density (Mg/m^3)		I R (mm/hr)	Available nutrients			
				0-15cm	15-30cm		N (kg/ha)	P (kg/ha)	K (kg/ha)	Zn (mg/kg)
CT	7.86	0.38	4.34	1.56	1.59	6.06	164	9.50	271	0.53
MT	7.81	0.40	4.36	1.55	1.58	6.11	169	9.70	276	0.54
ZT	7.72	0.39	4.42	1.49	1.55	6.76	178	10.14	284	0.58
CD (P=0.05)	NS	NS	0.06	0.06	0.04	0.29	5	0.26	4	0.03

CT-Conventional tillage, MT-Minimum tillage, ZT-Zero tillage, EC-Electrical conductivity, OC-Organic carbon, IR-Infiltration rate.

on surface soil, while there was slight increase in BD of sub-surface soil (15-30 cm) in all the treatments (Table 2). Tillage during longer period increases oxidation of OC resulting in higher BD (Franzluebbers 2002, Singh *et al*. 2019). Tillage practices did not significantly alter the BD of sub-soil (15-30 cm). The BD was slightly higher in 15-30 cm soil depth as compared to 0-15 cm.

The IR after harvest of wheat crop was significantly higher under ZT (6.8 mm/hr) as compared with CT (6.1 mm/hr), whereas IR was at par with both CT and MT. The higher IR under ZT might be due to greater continuity of soil pores and undisturbed dead root channels. Similarly Shukla *et al*. (2003) reported that tillage disrupts pore continuity and decreases IR. Available N, P, K and Zn after harvest of wheat crop was significantly influenced in ZT compared to MT and CT. Maximum additional availability of N, P, K and Zn were 14 kg, 0.64 kg, 13 kg/ha and 0.05 mg/kg soil as compared with the values under CT. Similarly, Singh *et al*. (2019) observed that continuous tillage degrades soil OC, which reduces nutrients availability as well as structure stability.

After harvest of *kharif* clusterbean crop wheat grown in *rabi* in arid and semi-arid regions of India. The seeding of wheat crop grown after clusterbean is delayed due to pre-irrigation and intensive tillage operations for seed bed preparation followed by farmers resulting in low yield in spite of utilization of high input of energy. Results of field trials concluded that DS of wheat in ZT conditions significantly influenced the growth parameters, yield, net profit, energy outcomes and WP as compared to conventional practices. The ZT seeding method of wheat significantly increased OC, IR, available N, P, K and Zn, while decreased of BD over MT and CT. It is concluded that under late sown conditions dry seeding of wheat with ZT just after harvest of clusterbean is the most promising option. Our study also suggested that seeding of wheat with ZT performed better in abnormal weather conditions (rains during reproductive stage) as compared with normal conditions.

REFERENCES

Devasenapathy P, Senthikumar G and Shanmugam M. 2009. Energy management in crop production. *Indian Journal of Agronomy* **54**: 80–90.

Franzluebbers A J. 2002. Water infiltration and soil structure related to OM and its stratification with depth. *Soil Tillage Research* **66**: 197–205.

Gupta M, Bali A S, Sharma S and Dixit A K. 2007. Potential role and influence of zero tillage technology on energy saving in rice-wheat system. *Indian Journal of Agricultural Science,* **77**: 657–9.

Hobbs P R and Morris M. 1996. Meeting south Asia's future food requirements from rice wheat copping systems: Priority issues facing researchers in post green revolution era. *Natural Resource Group Paper*, CIMMYT, Mexico, pp 96–101.

Kumar D and Solanki K S. 2013. *Solving the pulses crisis*. Guar. pp 317–38. Singh A K and Gangwar B (Eds). New India Publishing Agency, Pitampura, New Delhi.

Mulvaney M J, Verhulst N, Herrera J M and Govaerts B. 2014. Improved wheat performance with seed treatment under dry sowing on permanent raised beds. *Field Crop Research* **164**: 189–98.

Page A, Miller R H and Keeney D R. 1982. Method of soil analysis-Part 2. *Chemical and Microbiological Properties,* 2nd ed. Agron. Monogr. 9. ASA, CSSA, and SSSA, Madison WI.

Shukla M K, Lal R, Owens L W and Unkefer P. 2003. Land use and management impacts on structure and infiltration characteristics of soils in the North Appalachian region of Ohio. *Soil Science* **168**: 167–77.

Singh Y P, Singh D, Tomar S S and Gupta R K. 2013. Effect of time of pre-irrigation and tillage practices on wheat (*Triticum aestivum*) under pigeonpea (*Cajanus cajan*) – wheat cropping sequence. *India Journal of Agricultural Sciences* **83**: 1317–21.

Singh Y P, Singh Sudhir, Nanda Prabhakar and Singh A K. 2018. Establishment techniques and maturity duration of pigeonpea cultivar impact on yield, WP and soil properties. *Agricultural Research* **7**: 271–9.

Singh Y P, Singh Sudhir, Singh A K and Panwar Bhawani. 2019. Influence of wheat establishment techniques and previous *kharif* season crops on productivity, profitability, water use efficiency, energy indices and soil properties in Central India. *Agricultural Research* https://doi.org/10.1007/s40003-019-00420-y