

Doubling of yield, income, and enhancing water productivity

with conservation agriculture-based technologies

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The conventional production system has been facing serious challenges of soil and water degradation and declining profitability due to rising production cost in scarce irrigated areas of Farmers First Programme (FFP) project of Morena district of Madhya Pradesh. The conservation agriculture (CA)-based resource conserving technologies were demonstrated to overcome these problems. Results of CA-based innovative technological demonstrations indicated that precise land leveling (PLL) led to the improvement in grain yield of rainy season crops (pigeon pea, greengram, sesame, pearl millet and paddy) by 6.3-14.6% and of winter season crops (wheat, mustard and chick pea) by 13.2-17.8% as compared with traditionally leveled fields. Similarly, crops were established with zero tillage maximum with rainy season crops (5.0-9.9%) compared with conventional seeding practices. The crop established with PBBF was a maximum increase of rainy season crops (15.2-53.6%), whereas wheat grown after harvest of rainy season crop was increased by 6.4-8.8%, and mustard seed yield was increased by 11.9 and 17.7% of chick pea grown after harvesting of blackgram and greengram, respectively, as compared with conventional seeding methods. The study showed that the saving in cultivation cost and total water use, improvement in net benefits and water productivity of crops.

Key words: Conservation agriculture, Direct seeding, Land leveling, Precision, Semi-arid, Water productivity, Zero tillage

THE cultivation practices of limited irrigation water available areas are facing serious challenges of soil and water degradation, rising production cost and increasing uncertainty in the form of declining soil quality, intensive mono-cropping with adopting extensive tillage, imbalance use of nutrients, residue burning for catch crop, declining groundwater table, high wages and labour scarcity, direct or indirect biotic and abiotic climatic stresses. These factors are deteriorating the soil quality, adversely affecting crop yields, quality, profitability and also descending biodiversity, ecosystem and climatic conditions. It is, therefore, important to provide solutions to efficiently increase

agricultural productivity, profitability, soil quality and prevent degradation of natural resources, especially soil and water. For improving the biophysical and economic sustainability of cropping system, an innovative technology is a shift to conservation agriculture (CA) based cropping system. The CA has been identified as one of the technological options to meet the global challenges of increasing food production and conserving the environment, thereby improving food and nutritional security and alleviating poverty. Comprehensively, CA practices only refer to those practices with characteristics *viz.* soil cover, particularly through the retention of crop residues on the surface, rational

crop rotations, relaying of crops, precise land leveling and a minimum level of soil movement, e.g., reduced or zero tillage. These concepts are confined to achieve acceptable profits, greater and sustained production levels, and conserve the environment. The present study was attempted under the Farmer First Programme (FFP) on the replacement of existing crops with pulses crops, relaying of crops, CA-based leveling, and crop seeding methods compared with traditional practices on productivity, profitability, and water use efficiency.

Methodologies for conducting trials

The technology demonstrations were conducted under the FFP

project. Climate of the research study area is characterized in semi-arid, extremely cold during December-January (-1.0°C minimum temperature) and hot during May-June (49°C maximum temperature). The weekly average of the minimum and maximum relative humidity ranges from 23.8-89.0% and 38.0-91.1%, respectively. The average annual rainfall is 650 mm, mostly concentrated in July and August. Soils of the project area are neutral in nature and sandy loam in the texture of old alluvial plains. The soils were low in organic matter and available N, P, S, Zn, and medium in K. Water table varied from 25 to 31 m below the surface. Demonstrations on selected crops were carried out during rainy and winter season crops from 2016 to 2020 to evaluate the effect of CA-based technologies as compared with existing practices followed by the farmers. The demonstrations on crops namely pearl millet pigeon pea, greengram, blackgram, cluster bean, maize, paddy, wheat, mustard, chickpea, lentil, field pea was conducted. The recommended agronomical packages of practices of *Vishwa Vidyalyaya* were followed. Grain, straw yield, gross return, net return and cost-benefit ratio were calculated. Different economic indicators of inputs were calculated based on the minimum support price and existing market price. Total water use (input water) was computed by summing the irrigation water and rainfall. The total water use (irrigation + rainfall) and water productivity (WP) was computed by seed yield (kg/ha) divided by TWU (m^3/ha water).

Results of success for doubling of yield and income

Demonstrations were conducted in the FFP project to provide information on the effect of CA-based techniques on enhancing productivity, economic and water productivity of old alluvial plains of Morena district of Madhya Pradesh.



Fig. 1. Laser assisted leveling

Precise laser guided levelling

Impact on rainy season crops

Results indicated that Precision Land Leveling (PLL) led to an improvement in grain yield of rainy season crops (pigeon pea, greengram, sesame, pearl millet, and paddy) by 6.3-13.7% and straw yields 4.6-18.1% as compared with traditionally leveled fields (Table 1). The PLL improved the seed yield of paddy was maximum (13.7%) followed by pigeon pea (12.7%), pearl millet (9.6%), greengram (9.4%) and least with sesame (6.3%). Laser-assisted PLL has been able to improve the input-use efficiency of water and nutrients resulting in improved crop yields. Under land leveling demonstrations, slightly lower average production cost was recorded with PLL with all cropping systems due to savings in the cost of irrigation water and laborers compared with TLL. Adoption of PLL practice net savings of production cost was ₹ 500-3540/ha as compared with total cultivation cost under TLL (₹ 19,090-33,800/ha) of rainy season crops. The maximum additional savings in cultivation cost in paddy (₹ 3,540/ha) followed by pigeon pea (₹ 2,115/ha), green gram (₹ 1,600/ha), sesame (₹ 925/ha) and least with pearl millet (₹ 500/ha). The PLL technology had a maximum additional return of ₹ 13,938/ha with pigeon pea

followed by ₹ 13,603/ha with paddy, ₹ 12,659/ha with pearl millet, ₹ 6,475/ha with green gram and lowest with sesame crop (₹ 3,758/ha) as compared with TTraditional Land Levelling (TLL). The B:C ratio higher with PLL (2.7-4.1) as compared with TLL (2.2-3.4) was recorded.

The PLL technology was higher savings of TWU for producing crops as compared with TLL (Table 1). The TWU savings of rainy season crops with PLL demonstrations was higher with paddy ($500 \text{ m}^3/\text{ha}$) followed by pigeon pea ($198 \text{ m}^3/\text{ha}$), pearl millet ($144 \text{ m}^3/\text{ha}$), sesame ($135 \text{ m}^3/\text{ha}$) and lowest with green gram ($83 \text{ m}^3/\text{ha}$) as compared with TWU under TLL, respectively. The WP was also higher with PLL compared with TLL of all crops of rainy season crops under study. Overall in rainy season crops, the WP was increased under PLL from 20.7 to 29.4% compared with TLL. The WP of rainy season crops with PLL demonstrations was maximum obtained with pearl millet (29.4%) followed by sesame (25.6%), pigeon pea (24.3%), green gram (22.8%) and lowest with paddy (20.7%) as compared with TLL, respectively.

Impact on winter season crop

The PLL technology improved the grain yield of winter season crops (wheat, mustard, and chickpea) from 13.2 to 17.1% and straw yields 10.5-19.3% as compared with TLL (Table 1). The PLL improved the seed yield of mustard was maximum (17.1%) followed by wheat (14.9%) and least with chickpea (13.2%) crop. Adoption of PLL practice additional net savings of production cost was ₹ 400-1,542/ha as compared with total cultivation cost under TLL (₹ 24,230-29,422/ha) of winter season crops. The maximum additional savings in cultivation cost in wheat (₹ 1,542/ha) followed by mustard (₹ 1,125/ha) and least with chickpea (₹ 400/ha). The PLL technology was savings of TWU and producing a higher yield of crops

Table 1. Impact of laser guided precision land levelling on rainy and winter season crops

Crop	Interv- ention	No. of farmers	Grain yield (t/ha)	Stover yield (t/ha)	Cost of produ- ction (000₹/ha)	Net returns (000 ₹/ha)	B:C ratio	TWU (m³/ha water)	WP seed/ m³ water)
Rainy season crop									
Pigeon pea	CLL	146	1.65	5.73	28.6	67.5	3.4	6,360	0.24
	PLL		1.86	6.13	26.5	81.4	4.1	6,162	0.30
Greengram	CLL	199	0.85	1.65	19.9	31.7	2.6	3,058	0.26
	PLL		0.93	1.83	18.3	38.2	3.1	2,975	0.31
Sesame	CLL	76	0.79	2.93	19.1	26.7	2.4	4,415	0.16
	PLL		0.84	3.03	18.2	30.4	2.7	4,280	0.20
Pearl millet	CLL	167	3.24	7.81	22.2	38.3	2.7	4,260	0.67
	PLL		3.55	9.22	21.7	51.0	3.4	4,116	0.86
Paddy	CLL	31	4.54	5.42	33.8	39.9	2.2	8,260	0.55
	PLL		5.16	5.94	30.3	53.5	2.8	7,760	0.67
Winter season crop									
Wheat	CLL	214	3.95	5.68	29.4	56.1	2.9	3,660	1.1
	PLL		4.58	6.12	27.9	69.9	3.5	3,160	1.5
Mustard	CLL	282	1.81	5.18	26.0	52.3	3.0	1,770	1.0
	PLL		2.12	5.70	24.9	66.3	3.7	1,625	1.3
Chick pea	CLL	123	1.52	2.48	24.2	47.9	3.0	1,633	0.9
	PLL		1.72	2.95	23.8	58.2	3.4	1,560	1.1

CLL-Tractor driven conventional land levelling, PLL-Laser guided tractor driven precise land levelling, B:C- Benefit cost ratio, TWU-Total water use, WP-Water productivity

compared with TLL. The PLL technology had a maximum additional net return of ₹ 14,042/ha with mustard followed by ₹ 13,780/ha with wheat and lowest with chickpea crop (₹ 10,255/ha) as compared with TLL. The B:C ratio ranged from 3.4 to 3.7 with PLL, whereas 2.9 to 3.0 with TLL.

Additional savings of TWU of winter season crops with PLL was maximum with wheat (448 m³/ha) followed by mustard (145 m³/ha) and lowest with chickpea (73 m³/ha) as compared with TWU under TLL, respectively (Table 1). The WP was also higher with PLL as compared with TLL of all crops of winter season crops under study. Overall in winter season crops, the WP was increased with PLL demonstrations from 18.3 to 34.3% as compared with TLL. The WP of rainy season crops with PLL demonstrations was maximum obtained with wheat (34.3%) followed by mustard (28.4%) and lowest with chickpea (18.3%) as compared with TLL, respectively.

Crop diversification

Rainy season crops

In the present study, compared the cereal with pulse crops for their

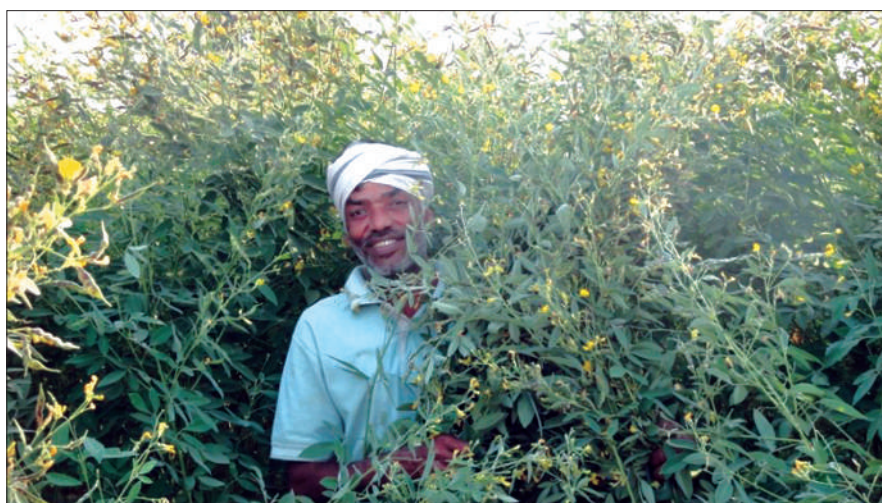
effects on productivity, profitability, TWU, and WP (Table 2). Results of the demonstrations indicated that the rainy season crop seed yield was obtained of pigeon pea 1.78 t/ha, greengram 0.90 t/ha, cluster bean 1.86 t/ha and pearl millet 2.81 t/ha. Among rainy season crops the higher production cost of pigeon pea (₹ 27,310/ha) followed by cluster bean (₹ 25,583/ha), pearl millet (₹ 22,110/ha) and lowest with green gram (₹ 18,910/ha). Similarly, net returns from the rainy season crops were followed the order: pigeon pea (₹ 79,260/ha) > cluster bean (₹ 79,260/ha) > green gram

(₹ 36,088/ha) > pearl millet (₹ 30,839/ha). The B:C ratio of rainy season crops was maximum recorded with pigeon pea (3.8) followed by greengram (2.9), cluster bean (2.6) and lowest with pearl millet (2.4).

Among various rainy season crops, the higher requirement of TWU for producing pigeon pea crop was 6211 m³/ha followed by cluster bean (5271 m³/ha), pearl millet (4275 m³/ha) and least with greengram (3018 m³/ha), whereas maximum WP was of pearl millet crop (0.657 kg seed/m³ water) followed by cluster bean (0.353 kg seed/m³ water), green gram (0.294 kg seed/m³ water) and lowest of pigeon pea (0.281 kg seed/m³ water) was recorded, respectively.

Winter season crop

The higher grain yield of wheat was obtained after greengram (5.26 t/ha) followed by pigeon pea (5.1 t/ha), pearl millet (4.88 t/ha) and lowest after cluster bean (4.49 t/ha), respectively (Table 2). The reduction in yield under late sown conditions, wheat crop growth period was reduced due to an increase of temperature beyond 30°C leads to forced maturity and yield loss. A similar trend of stover yield of wheat was also recorded. The cost of production of wheat crop grown after various cropping systems was varied and minimum with green gram (₹ 2,8018/ha), whereas maximum with cluster bean (₹ 29,892/ha) based cropping system. The trend of net returns of wheat was higher after harvest of greengram (₹ 80,298/ha)



Crop diversification

Table 2. Impact of rainy season crops and wheat grown after harvest of rainy season crops

Crop	No. of farmers	Grain yield (t/ha)	Stover yield (t/ha)	Cost of production (000 ₹/ha)	Net returns	B:C ratio	TWU (m ³ /ha water)	WP (kgseed/m ³ water)
<i>Rainy season crop</i>								
Pigeon pea	164	1.78	8.91	27.9	79.2	3.8	6,211	0.28
Green gram	191	0.80	2.03	18.9	26.1	2.9	3,018	0.29
Cluster bean	102	1.86	3.98	25.6	41.4	2.6	5,271	0.35
Pearl millet	239	2.81	7.11	22.1	30.8	2.4	4,275	0.66
<i>Winter season crop</i>								
Wheat after Pigeon pea	164	5.26	5.72	28.7	79.6	3.8	3,552	1.46
Wheat after Greengram	191	5.10	5.56	28.0	77.0	3.7	3,441	1.49
Wheat after Clusterbean	102	4.49	4.95	29.9	62.8	3.1	3,782	1.17
Wheat after Pearlmillet	239	4.88	5.14	29.0	71.0	3.5	3,502	1.37

B:C-Benefit cost ratio, TWU-Total water use, WP-Water productivity

followed by pigeon pea (₹ 76,385/ha), pearl millet (₹ 70,976/ha) and minimum with cluster bean (₹ 62,770/ha), respectively. The higher net return of wheat after the harvest of greengram was due to higher yield. Like net returns, a similar trend of B:C ratio of wheat were recorded in cropping systems.

In winter season, wheat grown after different rainy season crops required a varied amount of TWU (Table 2). The TWU was required of wheat was higher grown after cluster bean (3,782 m³/ha) followed by pigeon pea (3,552 m³/ha), pearl millet (3,502 m³/ha) and least with green gram (3,441 m³/ha), whereas, WP of wheat was higher after green gram (1.53 kg seed/m³) followed by pigeon pea (1.44 kg seed/m³), pearl

millet (1.37 kg seed/m³) and lowest with cluster bean (1.17 kg seed/m³) was recorded, respectively.

No-till farming

Rainy season crops

The demonstrations were conducted on rainy season crops (pigeon pea, cluster bean, maize, and paddy) on zero tillage seeding as compared with conventional tillage and seeding methods (Table 3). The results showed that compared with FP, yields of all rainy season crops were more when seeding of the crop with the ZT system. The additional gains in seed yield by 0.15 to 0.26 t/ha of rainy season crops. The gains in productivity with ZT was maximum with pigeon pea (9.9%) crop,

followed by cluster bean (9.7%), paddy (6.5%) and maize (4.4%) compared with yield under CT, respectively. Among rainy season crops, the higher production cost was saved with pigeon pea (₹ 5,405/ha) followed by paddy (₹ 5,362/ha), maize (₹ 5,295/ha) and lowest with cluster bean (₹ 4,974/ha) compared with a total cost of cultivation under CT. Similarly compared with total net returns under FP the additional net returns from the rainy season crops were followed the order: pigeon pea (₹ 14,935/ha) > cluster bean (₹ 10,244/ha) > maize (₹ 8,669/ha) > paddy (₹ 7,958/ha). The B:C ratio of rainy season crops was varied from 2.6 to 5.2 under ZT, whereas 1.1 to 3.8 under FP.

Among various rainy season crops,

Table 3. Impact of zero tillage seeding on rainy and winter season crops

Crop	Intervention	No. of farmers	Grain yield (t/ha)	Stover yield (t/ha)	Cost of production (000 ₹/ha)	Net returns (000 ₹/ha)	B:C ratio	TWU (m ³ /ha water)	WP (kg seed/m ³ water)
<i>Rainy season crop</i>									
Pigeon pea	CT	126	1.72	7.14	26.7	75.0	3.8	6,320	0.27
	ZT		1.89	7.43	21.3	89.9	5.2	6105	0.31
Cluster bean	CT	89	1.54	3.68	24.7	31.4	2.3	4,382	0.35
	ZT		1.69	3.85	19.7	41.6	3.1	4208	0.41
Maize	CT	36	4.74	6.19	25.9	49.7	2.9	4,927	0.97
	ZT		4.95	6.43	20.6	58.4	3.8	4711	1.04
Paddy	CT	41	4.02	4.30	31.4	33.9	2.1	8,493	0.47
	ZT		4.18	4.57	26.0	41.8	2.6	8039	0.52
<i>Winter season crop</i>									
Wheat after Pigeon pea	CT	126	4.52	4.89	29.2	63.8	3.2	3,460	1.31
	ZT		5.08	5.46	23.5	81.0	4.5	3,215	1.58
Wheat after Cluster bean	CT	89	3.94	4.05	30.5	49.9	2.6	3,791	1.04
	ZT		4.27	4.49	25.0	62.5	3.5	3,506	1.22
Wheat after Maize	CT	36	4.63	4.95	28.8	66.3	3.3	3,408	1.36
	ZT		4.83	5.20	23.3	76.1	4.3	3,226	1.50
Wheat after Paddy	CT	41	4.35	4.71	28.0	61.5	3.2	3,182	1.37
	ZT		4.62	5.12	23.4	72.1	4.1	2,944	1.56

CT-Tractor driven conventional tillage and seeding, ZT-Zero tillage seeding with zero till seed cum fertilizer drill, B:C- Benefit cost ratio, TWU-Total water use, WP-Water productivity

the savings of additional TWU for producing paddy crop was 454 m³/ha followed by maize 216 m³/ha, pigeon pea 215 m³/ha and least with cluster bean 174 m³/ha as compared with TWU under CT (Table 3). Similarly TWU for rainy season crops were followed the order: paddy (8,039 m³/ha) > pigeon pea (6,105 m³/ha) > maize (4,711 m³/ha) > cluster bean (4,208 m³/ha), whereas maximum WP was in followed the order: maize (1.04 kg seed/m³ water) > paddy (0.52 kg seed/m³ water) > cluster bean (0.41 kg seed/m³ water) > pigeon pea (0.281 kg seed/m³ water) was recorded in ZT demonstrations, respectively.

Winter season crops

The demonstrations showed that the higher additional grain yield was obtained from 0.20 to 0.56 t/ha under ZT as compared with CT (Table 3). The higher additional grain yield of wheat was obtained after pigeon pea (0.56 t/ha) followed by cluster bean (0.33 t/ha), paddy (0.27 t/ha) and lowest after maize (0.20 t/ha) as compared with total yield under CT, respectively. A similar response was obtained in the stover yield of wheat crop. The additional savings of production cost from ₹ 4,681 to 5,734/ha as compared with the total cost of production under CT. The additional net returns of wheat crop grown after pigeon pea (₹ 1,7148/ha), whereas cluster bean (₹ 12,588/ha), paddy (₹ 10,590/ha) and maize (₹ 9,775/ha) as compared with total net returns under CT, respectively. The B:C ratio also increased under ZT as compared with CT. In winter season wheat crop grown after rainy season crops were required a higher amount of TWU after cluster bean and minimum after paddy. The savings of TWU with ZT was 182 to 285 m³/ha as compared with CT. The WP varied from 1.22 to 1.58 kg seed/m³ water under ZT, whereas 1.04 to 1.31 kg seed/m³ under CT was recorded, respectively.

Permanent Broad bed

Rainy season crops

The demonstrations were

conducted on rainy season crops (pigeon pea, cluster bean, greengram, blackgram) of PBBF seeding as compared with conventional tillage and seeding methods (Table 4). Results showed that compared with CT, yields of all crops were more when seeded on the PBBF system. The gain in productivity with PBBF was a maximum of green gram (53.1%) crop, followed by black gram (32.9%), pigeon pea (19.8%) and cluster bean (15.2%) as compared with CT. The net cultivation cost savings from ₹ 3,475 to 6,070 with PBBF as compared with the total cultivation cost of rainy season crops. The minimum cost of production with PBBF was mainly due to savings in the cost of tillage, irrigation water, and men power. The trend of the cost of production of rainy season crops was in order: pigeon pea > cluster bean > black gram > green gram. Maximum additional net returns of rainy season crops were maximum with pigeon pea (₹ 27,346/ha) followed by green gram (₹ 23,905/ha), black gram (₹ 13,424/ha) and least with cluster bean (₹ 13,211/ha) with PBBF as compared with total net returns of rainy season crops with CT, respectively. The higher net return with the PBBF system was due to a saving of cost in cultivation and higher yield.

All over the pooled data showed that the amount of TWU for all the rainy season crops was lesser in PBBF as compared with CT (Table 4). The savings of TWU of pigeon pea was 10.1% and 6.4% of cluster bean, whereas negligible savings with green gram and black gram as compared with CT due to crops matured with rainwater. The higher yield with using less water resulting in a maximum increase of WP with green gram was 54.7% followed by black gram (35.9%), pigeon pea (34.1%) and least with cluster bean (27.2%) as compared with CT.

Winter season crops

The maximum seed yield of wheat, mustard and chickpea were more when the crop was seeded on the PBBF as compared with CT (Table 4). The gains in productivity with

PBBF of wheat was 6.2% higher grown after pigeon pea and 7.8% after cluster bean, whereas mustard and chick pea seed yield was increased by 11.9 and 17.7% grown after blackgram and greengram, respectively, as compared with CT. Similar response was also obtained of stover yield. The net cultivation cost savings in ₹ 6,447-6,649/ha of wheat, whereas ₹ 5,784/ha of mustard and ₹ 4,925/ha of chickpea with PBBF as compared with the total cost of cultivation under CT. The minimum cost of production with PBBF was mainly due to savings in the cost of tillage, irrigation water, and men power. Similarly, net returns were higher with PBBF as compared with CT. Additional net returns of wheat were ₹ 12,019-12,891/ha under PBBF as compared with total net returns of ₹ 63,703 and 51,866/ha grown after pigeon pea and cluster bean with CT, respectively. Consistent with our results were due to higher net returns and reduction in the cost of cultivation and higher yield with PBBF. The B:C ratio of wheat with different seeding techniques also higher under PBBF as compared with CT. The lowest net income and B:C ratio with CT was owing to the highest cost of cultivation and lower yield of wheat.

The savings of TWU of wheat crop grown after cluster bean was 21.9% and 20.3% after pigeon pea, whereas savings with chickpea crop with 22.3% grown after green gram and 24.2% of mustard after black gram under PBBF as compared with CT, respectively (Table 4). Similarly, WP was maximum with PBBF seeding of chickpea crop (55.7%) grown after green gram followed 40.0% with mustard after black gram, whereas 38.4% and 33.2% with wheat grown after cluster bean and pigeon pea, respectively, as compared with CT.

Dry seeding

The seeding of wheat after the harvest of toria (*Brassica rapa*) and cluster bean is generally delayed due to late maturity, pre-irrigation and seedbed preparations. The increase in grain and straw yields by 12.5% and 9.4% were observed with DS as

Table 4. Impact of permanent broad bed furrow seeding on rainy and winter season crops

Crop	Intervention	No. of farmers	Grain yield (t/ha)	Stover yield (t/ha)	Cost of production (000 ₹/ha)	Net returns (000 ₹/ha)	B:C ratio	TWU (m³/ha water)	WP (kg seed/m³ water)
Rainy season crop									
Pigeon pea	CT	49	1.97	6.95	28.2	86.2	4.1	6,184	0.32
	PBBF		2.36	7.24	22.1	113.5	6.1	5,560	0.43
Green gram	CT	58	0.64	1.68	19.1	20.1	2.1	3,182	0.20
	PBBF		0.98	2.06	15.6	44.0	3.8	3,127	0.31
Cluster bean	CT	29	1.52	3.37	26.9	28.1	2.0	4,381	0.35
	PBBF		1.75	3.92	21.5	41.3	2.9	4,003	0.44
Black gram	CT	28	0.76	1.82	20.0	21.9	2.1	3,294	0.23
	PBBF		1.01	2.15	15.7	39.7	3.5	3,210	0.31
Winter season crop									
Wheat after pigeon pea	CT	49	4.50	4.92	29.0	63.7	3.2	3,490	1.29
	PBBF		4.78	5.16	22.6	75.7	4.4	2,783	1.72
Wheat after Cluster bean	CT	58	3.95	4.46	30.0	51.9	2.7	3,691	1.07
	PBBF		4.26	4.75	23.3	64.8	3.8	2,884	1.48
Mustard after Black gram	CT	29	2.19	5.99	26.0	68.4	3.6	1,775	1.23
	PBBF		2.45	6.53	20.2	85.2	5.2	1,346	1.82
Chick pea after Green gram	CT	28	1.72	2.31	24.6	55.8	3.3	1,698	1.02
	PBBF		2.09	2.68	19.7	77.7	4.9	1,320	1.59

CT-Tractor driven conventional tillage and seeding, PBBF-Seeding of crop on permanent bed with broad bed seed cum fertilizer drill, B:C-Benefit cost ratio, TWU-Total water use, WP-Water productivity

compared to CS. Total water-use under the CS method was significantly higher as compared with DS, whereas the reverse trend was observed in water productivity. The study reveals that to maximize yield, profit, water productivity, improved physicochemical properties of soil, saved energy and resources with dry seeding of wheat just after harvest of cluster bean without any tillage and irrigation for germination in sandy loam soil. The savings of TWU of wheat crop grown with dry seeding

after cluster bean and toria was 21.9% and 20.3%, respectively as compared with pre-irrigation before seeding of the crop. Similarly, WP was maximum with dry seeding of wheat after cluster bean and toria were 1.38 and 1.32 kg seed/m³ water, whereas these values were 1.07 and 1.01 kg seed/m³ water in pre-irrigation before seeding of crop.

Residue retention through happy seeder seeding

In combine harvested areas,

managing of rice, maize, pearl millet, and wheat residues is the major issue. Farmers generally burn crop residue prior to seeding as the cheap and easy option for residue management, but burning leads to losses of soil organic matter, nutrients and create environmental pollution. Results of the demonstrations showed that the productivity of wheat was increased up to 12% in grain and 6.9% in straw with the establishment of the crop with happy seeder as compared with grain (4.28t/ha) and straw

Table 6. Impact of dry seeding of rainy and winter season crops

Crop	Intervention	No. of farmers	Grain yield (t/ha)	Stover yield (t/ha)	Cost of production (000 ₹/ha)	Net returns (000 ₹/ha)	B:C ratio	TWU (m ³ /ha water)	WP (kg seed/m ³ water)
Wheat after	FP	14	3.95	4.23	29.6	51.6	2.7	3,685	1.07
Cluster bean	CA		4.42	4.72	24.1	66.7	3.8	3,204	1.38
Wheat after	FP	6	3.81	4.18	30.4	48.2	2.6	3,760	1.01
Toria	CA		4.29	4.55	25.9	62.1	3.4	3,255	1.32

FP-Pre-irrigation before seeding of crop, IP-Dry seeding with zero till seed cum fertilizer drill, TWU-Total water use, WP-Water productivity

Table 7. Impact of residue retention of previous crop on rainy and winter season crops

Crop	Intervention	No. of farmers	Grain yield (t/ha)	Stover yield (t/ha)	Cost of production (000 ₹/ha)	Net returns (000 ₹/ha)	B:C ratio	TWU (m ³ /ha water)	WP (kg seed/m ³ water)
Wheat after pearl millet	FP	39	4.32	4.91	29.9	59.7	3.0	3,761	1.15
	CA		4.69	5.40	25.0	72.5	3.9	3,407	1.38
Wheat after maize	FP	19	4.53	5.35	30.0	64.6	3.2	3,655	1.24
	CA		4.99	5.62	25.4	77.9	4.1	3,318	1.50
Wheat after paddy	FP	11	4.17	4.65	29.0	57.3	3.0	3,562	1.17
	CA		4.48	5.14	24.2	68.9	3.9	3,204	1.40

FP-Burning or residue removal of previous crops and traditional practice of seeding, IP-Residue retention of previous crop through seeding of crop through happy seeder, TWU-Total water use, WP-Water productivity



Fig. 2. Direct seeding of wheat after harvest of pigeon pea



Fig. 3. Relay cropping

Table 8. Impact of system of relay cropping of berseem in mustard in pearl millet based cropping system

Intervention of crops	No.	Crop	Seed yield (t/ha)	Stover yield (t/ha)	Production cost (000 ₹/ha)	Net return (000 ₹/ha)	B:C ratio	TWU (m ³ /ha water)	WP (kg seed/m ³ water)
Peal millet – Mustard	24	Pearl millet	2.39	7.90	22.5	24.4	2.1	4,392	0.54
		Mustard	1.75	4.02	26.4	48.0	2.8	2,216	0.79
		Total	-	-	48.9	72.4	2.5	6,608	-
Pearl millet – Mustard + Berseem	24	Pearl millet	2.72	8.05	22.2	30.6	2.5	4,321	0.63
		Mustard	1.96	4.83	26.0	54.1	3.1	2,150	0.91
		Berseem	0.42	2.81	16.5	43.4	4.2	1,853	0.90
		Total	-	-	64.7	128.1	3.1	8,324	-

No.-Number of farmers, TWU-Total water use, WP-Water productivity

(5.87t/ha) traditional practice of seeding (Fig. 2). The net cultivation cost savings from ₹ 4,600 to 5,600/ha with happy seeder compared with the total cost of cultivation of ₹ 28,888 to 29,900/ha of wheat. The minimum cost of production with happy seeder was mainly due to savings in the cost of tillage and irrigation water. The higher net return with happy seeder system was due to saving of cost in cultivation and higher yield. The savings of TWU of wheat crop seeding with happy seeder after harvest of pearl millet, maize and paddy were 9.4, 9.2 and 10.1%, respectively as compared with traditional practice of seeding. Like-wise WP of wheat crop was maximum with seeding of crop with happy seeder and these values after pearl millet, maize and paddy were 1.38, 1.50 and 1.40 kg seed/m³ water, whereas 1.15, 1.24 and 1.17 kg seed/m³ water with traditional practice of seeding.

Relay cropping

Pearl millet and mustard are important food grain and oilseed cropping system in India. Inclusion of forage legume (berseem) crop in relay

cropping in mustard-based pearl millet system increased productivity by 13.8% of pearl millet and 12.0% in mustard crop as compared with mono-cropping system yield of pearl millet and mustard (Fig. 3). The cultivation of berseem provides 2.8 tones green fodder/ha just in one cutting and 0.42 t/ha seed. The study showed that diversification of mono-cropping (pearl millet - mustard) with relay cropping (pearl millet - mustard + berseem) gave the additional benefit of ₹ 35,658/ha compared to the total net income of mono-cropping ₹ 72,393/ha. The seed production increased the income of farmers and also acted as flora for honey bees. This practice is supporting dairying and beekeeping enterprises. The B:C ratio of peal millet - mustard cropping system was 2.5, whereas 3.1 of pearl millet - mustard + berseem relay cropping system. The additional TWU of relaying berseem in mustard crop grown in pearl millet based cropping system was 26.0% greater as compared with TWU of pearl millet-mustard based cropping system (6,608 m³/ha water). Similarly, WP was increased with relaying berseem in

mustard crop grown in pearl millet based cropping system.

Conclusion

CA offers an opportunity and a mission to move into the next phase in agriculture. It is a challenge for all stakeholders, the scientific community, farmers, extension agencies and industry to understand the opportunities, and call for strategies different from those we have adopted over the past decades in conventional agriculture. CA offers an opportunity for arresting and reversing the downward spiral of resource degradation, decreasing cultivation costs and making agriculture more resource – use-efficient, competitive and sustainable. The results of CA based technologies in FFP project showed that the conserving resources can be applied for enhancing productivity, profitability and water productivity in a new mission mode.

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