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Conservation agriculture practices in Indian mustard (*Brassica juncea*)-based cropping systems for enhanced productivity and profitability

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ABSTRACT

The present study was carried out during 2019–20 and 2020–21 at the research farm of ICAR-Directorate of Rapeseed-Mustard Research, Bharatpur, Rajasthan to scale out the conservation agriculture (CA) practices in Indian mustard [*Brassica juncea* (L.) Czern.]-based cropping systems for enhancing production and farm profitability. Experiment was conducted in the split-plot design (SPD) after randomization, and replicated three times in the permanent plots. The treatment comprised of 3-tillage and crop residue re-cycling [permanent beds with residue (PB+R); zero tillage with residue (ZT+R); and conventional tillage without residue (CT-R)] in main-plots; and 6-oilseed brassica-based cropping systems [Fallow-mustard (F-M); Cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.]-mustard (CB-M); Greengram [*Vigna radiata* (L.) R. Wilczek-mustard (GG-M); Maize (*Zea mays* L.)-mustard (Mz-M); Pearl millet [*Pennisetum glaucum* (L.) R. Br.]-mustard (PM-M); and Sesame (*Sesamum indicum* L.)-mustard (S-M)] in sub-plots. The mean mustard seed yield increased 28 and 11% under permanent beds with residue (PB+R) and zero tillage with residue (ZT+R) compared to conventional tillage without residue (CT-R), respectively. The mean seed yield of *kharif* crops also increased by 37.1 and 31.7% in the PB+R and ZT+R compared to CT-R, respectively. The maize-mustard (Mz-M) cropping system recorded significantly higher yield of mustard across the years followed by greengram-mustard (GG-M) cropping system. The mean mustard equivalent yield (MEY) increased by 33.4 and 24.2% in PB+R and ZT+R over the CT-R, respectively. The total system grain yield (TSGY) also increased by 29.6 and 14.7% in the PB+R and ZT+R over the CT-R, respectively. Among the cropping systems, GG-M followed by Mz-M system recorded highest MEY and TSGY in both the years. The Mz-M cropping system under PB+R recorded maximum net returns and B:C ratio which was higher by 40.7 and 41.1 compared to traditional F-M cropping system under CT-R, respectively. Thus, CA-based Mz-M/GG-M system should be out scaled in the traditional rainfed mustard based production system to improve the farm production and income on holistic basis to increase the edible oil production in the country.

Keywords: Conservation agriculture, Indian mustard, Productivity, Profitability

India is fourth largest vegetable oil economy in the world next to USA, China and Brazil. Globally, it is grown on 41.95 million hectare (Mha) area and contribute 88.35 million tonne (Mt) in oilseed basket with average yield of 2110 kg/ha (FAOSTAT 2022). In India it is cultivated on 7.99 Mha area and contribute 11.96 Mt in production with average yield of 1497 kg/ha (Anonymous 2022). Rapeseed-mustard is also an important oilseed crop of India sharing second position in area (25%) and third in production (24%) among total oilseeds. Indian mustard [*Brassica juncea* (L.) Czern.] holds sizable contribution, however, the productivity levels are 2/3rd of the world level due to large scale cultivation under rainfed situation, biotic and abiotic stresses, and resources crunch (Kumar 2012, Jat *et al.* 2019).

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The conventional rapeseed mustard production system largely suffers due to excessive tillage, poor crop establishment and monotonous cropping system which exaggerate the resource degradation and cost of production. Undesired excessive tillage practices for field preparation (Shekhawat *et al.* 2016) leads to breakdown of soil organic carbon, organic matter (Gathala *et al.* 2011) which decline the soil fertility and microbial population. It also leads to early exhaustion of soil moisture which is a major apprehension in the rainfed ecology. Conservation agriculture (CA), comprising minimum soil disturbance, organic mulch cover and crop diversification in conjunction with other good practices of crop and production management are now practiced globally on about 205.4 million hectares in all continents and all agricultural ecologies (Kassam *et al.* 2022). CA practices expanding at an annual rate of 10 Mha since 2008–09 and covered 14.7% of global crop land area. Reports revealed that CA practices reduced production costs, improved water use efficiency, and sustained or increased crop productivity across the globe in the present era of resource degradation and climate change (Hobbs 2007, Das *et al.* 2014, Parihar *et al.* 2018). Conservation agriculture based system intensification in the vulnerable semi-arid tropics provides opportunities to conserve and utilize the fatiguing natural resources more efficiently, resilience to anomalous climatic events, and to increase productivity and farmers' profitability while minimizing production cost and energy. Besides this, crop intensification improves the nutritional security of the farm households and reduces the risk of total crop failure in unfavorable or erratic weather situations (FAO 2013). Considering various arguments, the CA must obviously be adapted to local agro-ecological conditions and farmer capabilities and preferences. Fundamentally, to derive maximum benefit from CA, location-specific appropriate crop rotations and system-based CA practices need to be standardized (Das *et al.* 2018, Kassam *et al.* 2018).

Indian mustard, a versatile oilseed crop of semi-arid tropics, needs system based approaches at appropriate scale to exploit the production potential while enduring the growing climatic stresses. CA-based sustainable intensification of the traditional fallow-mustard system in the rainfed ecology holds promises to address the shortfall of oilseed and edible oil in the country and reduce the import burden. Therefore, the present study was planned to insights on sustainable and economical CA-based Indian mustard systems for semi-arid climates in India.

MATERIALS AND METHODS

An experiment was conducted during 2019–20 and 2020–21 at the research farm of ICAR-Directorate of Rapeseed-Mustard Research, Bharatpur (77°3' E, 27°15' N and altitude of 178.37 m amsl), Rajasthan. The climate was semi-arid, characterized with wide range of temperature between summer (*kharif*) and winter (*rabi*) with good rainfall in the *kharif* (July, August and September) as well in *rabi* (November, December and January) which favoured the crop growth and development. However, rain received in the month of March during 2019–20 has adversely affected the crop at the time of maturity. The meteorological observations were recorded daily and averaged to monthly during the crop growth period (Fig. 1). The soil *p*H and EC of the experimental site were 8.3 and 1.3 dS/m, respectively. The soil samples were collected at the time of sowing and analyzed poor in organic carbon (2.4 g/kg) and available N (126.3 kg/ha), while medium in 0.5 N $NaHCO_3$ extractable P (17.2 kg/ha) and 1.0N NH4OAc exchangeable K (149.3 kg/ha). The bulk density of soil was 1.52 Mg/m^3.

The treatment comprised of 3-tillage and crop residue re-cycling [permanent beds with residue (PB+R); zero tillage with residue (ZT+R); and conventional tillage without residue (CT-R)] in main-plots, and 6-oilseed brassica-based cropping systems [Fallow-mustard (F-M); Cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.]-mustard (CB-M); Greengram [*Vigna radiata* (L.) R. Wilczek-mustard (GG-M); Maize (*Zea mays* L.)-mustard (Mz-M); Pearl millet [*Pennisetum glaucum* (L.) R. Br.]-mustard (PM-M); and Sesame (*Sesamum indicum* L.)-mustard (S-M)] in sub-plots. Thus, in total 18 interactions were allocated in the split-plot design (SPD) after randomization, and replicated three times in the permanent plots. Best crop management practices were followed in all the treatments. System-wise residue retained were; 2.3, 2.5, 3.8, 4.2, 3.1, and 2.7 t/ha in PB+R; and 2.4, 2.4, 3.7, 3.7, 3.3 and 2.3 t/ha in ZT+R under F-M, CB-M, GG-M, Mz-M, PM-M, and S-M systems, respectively. Both dry as well as rainy season crops were optimally nourished with their respective recommended doses of macro and micronutrients except 20% additional N applied to PB and ZT plots in Indian mustard.

Crop establishment: The experiment was initiated with deep ploughing (30 cm) with chisel plough to break the hard pan and leveled. The wet season crops were sown as per standard practices and treatments of interest. The raised beds were prepared and sown the crops simultaneously with raised bed planter attached with seed cum fertilizer drill. These beds were maintained for succeeding crops in cycle as permanent beds. In zero tillage plots, the crops were sown with zero till planter attached with seed cum fertilizer drill. The conventional tillage crops were sown after sequential tillage operations like harrowing (1), spring-tyne cultivator (5) and leveling (3) as the farmers' practicing in the region. Each crop was sown in 15 m × 6.4 m gross plot area and plant and soil observations were taken from 14 m × 5.4 m net sown area of each treatment.

Yield of crops and system grain yield: Equal number of rows of each crop was harvested manually from net plot area (14 m × 5.4 m)

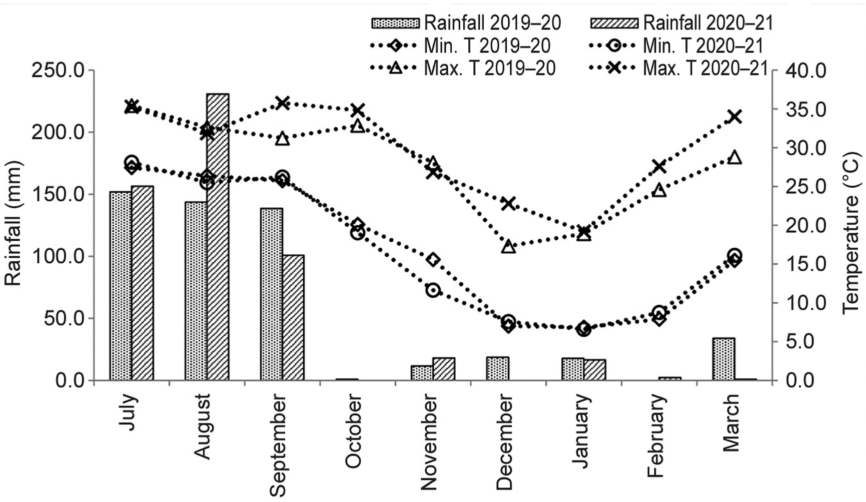

Fig. 1 Seasonal maximum and minimum temperature and rainfall during 2019–20 and 2020–21.

leaving anchored stubbles in the field as per treatments. The harvested produce was sun dried and threshed using mechanical thresher (maize grains separated with the sheller). The stubbles left over in the field of each crop were measured using 1.0 m^2 quadrant at three places from net plot and sun dried. The stover yield was adjusted to the amount left in the field for total stover yield/ha. The system productivity of different cropping systems was measured in to Indian mustard equivalent yield (MEY) and total system grain yield (TSGY) by converting yield of non-Indian mustard crops in to Indian mustard using equation as:

$$\text{Mustard equivalent yield (kg/ha)} = \frac{\text{Yield of } kharif \text{ crop (kg/ha)} \times \text{Minimum support price of } kharif \text{ crop (₹/kg)}}{\text{Minimum support price of } kharif \text{ crop (₹/kg)}}$$

Total system grain yield (kg/ha) = Mustard equivalent yield (kg/ha) + Mustard seed yield (kg/ha)

Economic returns: The economic analysis was worked out for mustard under the respective treatments. The total cost of cultivation includes all the input and related costs (field, labour, and electricity) that are involved in crop production from sowing to marketing. Gross returns were calculated by multiplying the crop yield by the minimum support price that was offered by the Government of India (GoI), and the straw yield by current local market rates. The net returns (NR) were calculated as the difference between the GR and the TC (NR = GR-TC). The system NRs were calculated by adding NRs of crops harvested within an individual calendar year. The benefit cost ratio was calculated from NR and TC of cultivation (B:C ratio = NR/TC).

Statistical analysis: The data were subjected to analysis of variance for critical differences using SSCNARS Portal online data analysis tool, IASRI (http://www.iasri.res.in/sscnars/2016). Treatment means were separated by Duncan Multiple Range Test at 5% level of significance. The multiple least significant differences were worked out at $P<0.05$ probability level from each data set.

RESULTS AND DISCUSSION

Effect on seed yield of crops: The tillage and residue retention not influenced seed yield of mustard significantly during first year, however, increased markedly of *kharif* crops as well as mustard in the 2nd year of experiments. Permanent beds with residue (PB+R) recorded highest seed yield of mustard as well as *kharif* crops followed by zero tillage with residue (ZT+R) and the lowest in the conventional tillage without residue (CT-R). The mean mustard seed yield increased 28 and 11% in PB+R and ZT+R compared to CT-R, respectively (Table 1). The mean seed yield of *kharif* crops were also recorded higher by 37.1 and 31.7% in the PB+R and ZT+R compared to CT-R, respectively (Table 1). Bed planting improved yield of mustard as well as crops in the system due to better plant establishment, root development, optimum fertilizer placement, and improved soil physicochemical and biological properties. Higher productivity and profitability in CA-based management was reported in mustard (Nandan *et al.* 2013) and sesame based cropping system (Oyeogbe *et al.* 2015) compared to monocropping. Permanent bed planting ensured higher mustard yield due to complementary border effects (Singh and Kharub 2001) which are more under residue retention than conventional tillage without residue.

Diversification of traditional fallow-mustard system with *kharif* crops (cluster bean, green gram, maize, pearl

Table 1 Effect of tillage, residue retention and cropping systems on seed yield (kg/ha) of *kharif* crops and Indian mustard

	2019–20		2020–21		Mean	
	Mustard	*Kharif* crop	Mustard	*Kharif* crop	Mustard	*Kharif* crop
Tillage practice						
PB+R	2897	1649	2993	1932	2945	1791
ZT+R	2603	1734	2502	1706	2553	1720
CT-R	2365	1326	2234	1286	2300	1306
S.Em.±	74	80	47	8	27	37
CD (*P*=0.05)	291	314	185	31	105	144
Cropping system						
F-M	2617	0	2536	0	2577	867
CB-M	2661	863	2663	871	2662	1270
GG-M	2727	1251	2680	1289	2703	4186
Mz-M	2753	4581	2835	3791	2794	2656
PM-M	2549	2080	2231	3232	2390	655
S-M	2424	644	2513	667	2469	60
S.Em.±	51	122	85	10	47	174
CD (*P*=0.05)	147	353	246	28	135	867

Treatment details are given under Materials and Methods.

millet and sesame) followed by mustard was explored. The mean yield of mustard was recorded higher in CB-M, GG-M and Mz-M cropping system, and lower yield in PM-M and S-M cropping system in comparison to F-M system. Among the cropping systems, Mz-M cropping system recorded significantly higher yield of mustard as well as maize in the system across the years followed by GG-M cropping system (Table 1). On an average, the Mz-M, GG-M and CB-M cropping systems increased mustard yield by 8.4, 4.9 and 3.4% over the traditional fallow-mustard system. This might be due to favourable soil-plant-environment continuum in the permanent beds complementary with residues resulted into higher biomass and system yield. CA-based system reported to increased mustard yield, higher system productivity in the rice-mustard (Jakhar *et al.* 2018, Das *et al.* 2020).

Effect on MEY and TSGY: The mustard equivalent yield of *kharif* crops and the total system grain yield recorded significantly higher in the PB+R in both the years followed by ZT+R except first year (Table 2). The mean MEY increased by 33.4 and 24.2% in PB+R and ZT+R over the CT-R, respectively. The TSGY was also recorded higher by 29.6 and 14.7% in the PB+R and ZT+R over the CT-R, respectively. Among the cropping systems, GG-M followed by Mz-M system recorded highest MEY and TSGY in both the years. The mean TSGY increased by 82.3 and 73% in GG-M and Mz-M cropping system over the traditional F-M system (Table 2).

Interaction effects of tillage practices and residue retention, and cropping systems were found significant with respect to MEY and TSGY. The interaction effects showed that MEY was recorded maximum in the GG-M (2188 kg/ha) followed by Mz-M (1848 kg/ha) cropping system under PB+R which were additional yield from *kharif* season to the farmers' compared to zero yield in the traditional F-M system (Fig. 2). The TSGY was also recorded highest in the GG-M followed by Mz-M cropping system under PB+R which was 54.6 and 46.3% higher over the traditional F-M system under CT-R, respectively. Thus, CA-based diversification of mustard-based system with *kharif* crops

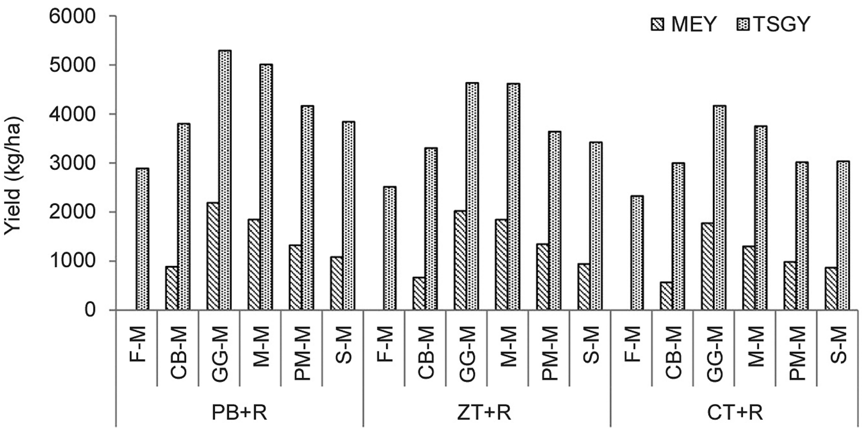

Fig. 2 Effect of conservation agriculture practices on mustard equivalent yield (MEY) and total system grain yield (TSGY).
Treatment details are given under Materials and Methods.

Table 2 Effect of tillage, residue retention and cropping systems on mustard equivalent yield (MEY) and total system grain yield (TSGY) (kg/ha)

	2019–20		2020–21		Mean	
	MEY	TSGY	MEY	TSGY	MEY	TSGY
Tillage practice						
PB+R	1160	4057	1282	4275	1221	4166
ZT+R	1124	3728	1149	3651	1136	3689
CT-R	906	3271	925	3159	915	3215
S.Em.±	38	87	7	49	16	37
CD (*P*=0.05)	149	340	29	194	64	147
Cropping system						
F-M	0	2617	0	2536	0	2577
CB-M	683	3343	730	3394	706	3368
GG-M	1992	4719	1995	4676	1994	4697
Mz-M	1822	4575	1508	4343	1665	4459
PM-M	940	3489	1494	3725	1217	3607
S-M	944	3368	983	3496	963	3432
S.Em.±	56	56	11	88	29	61
CD (*P*=0.05)	163	162	33	254	83	175

Treatment details are given under Materials and Methods.

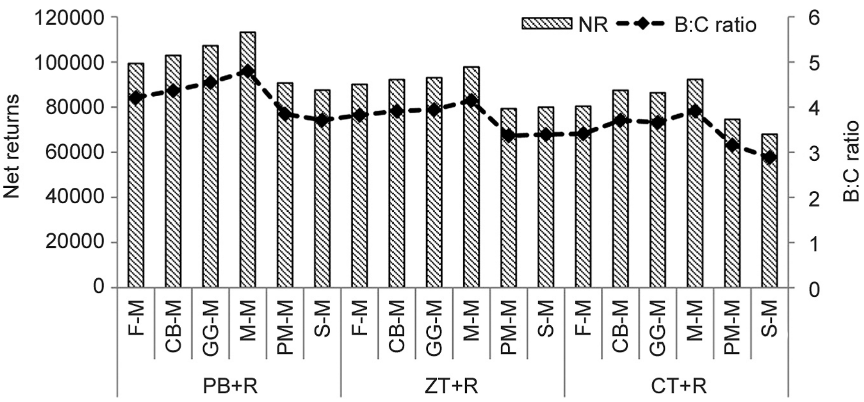

Fig. 3 Net returns and B:C ratio influenced with CA practices. Treatment details are given Materials and Methods.

increased the system grain yield >50% than the traditional fallow-mustard system.

Economic returns: The net return and the benefit cost ratio were influenced markedly with tillage and residue retention, and cropping systems (Fig. 3). PB+R recorded maximum net returns across the cropping systems followed by ZT+R and lowest in the CT-R. The PB+R in Mz-M cropping system accrued maximum net returns across the tillage and residue management practices followed by GG-M cropping system. The PM-M and S-M cropping systems were recorded lowest net returns even lower than F-M system. The B:C ratio recorded maximum in PB+R across the cropping systems followed by Mz-M cropping system (Fig. 3). The lowest B:C ratio was recorded in the PM-M and S-M cropping systems in all the management practices. Overall, the Mz-M cropping system under PB+R recorded maximum net returns and B:C ratio which was higher by 40.7 and 41.1% compared to traditional F-M cropping system under CT-R, respectively. The next remunerative cropping system was found GG-M which has accrued 33.7 and 32.4% higher net returns and B:C ratio under PB+R compared to traditional F-M cropping system under CT-R, respectively. Increased yield of the component crops in the system under permanent beds with residue and crop diversification might be due to the complementary effects of each other resulted into less production cost and higher net return. Combined, these results clearly demonstrate the potential of CA towards sustainable intensification of crop production to improve future household income and food security (Pradhan *et al.* 2018).

Crop diversification showed the potential to adapt the changing climate with greater productivity and profitability. Conservation tillage in mustard based cropping systems proved better in achieving the *kharif* as well as *rabi* crops yield and system productivity. Diversification with GG-M and Mz-M cropping system doubled the mustard equivalent yield and total system grain yield under CA based management (PB+R) compared to traditional fallow-mustard system. Intensification of CT-based fallow-mustard systems through the CA-based maize-mustard system provided more economic returns and benefits. This climate-smart strategy of crop diversification encourages a new paradigm for sustainable and ecological intensification of mustard based production system. The intensification of land to produce crop throughout the seasons has become a basis to sustainably increased crop production capable of feeding the increasing population with dwindling and unproductive land area.

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