



Tillage and residue retention effect on crop and water productivity of Indian mustard (*Brassica juncea*) under rainfed conditions

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ABSTRACT

A field experiment was conducted during *rabi* season of 2014-15 and 2015-16 to study the effect of moisture conservation techniques and tillage management practices on growth, productivity and economics of Indian mustard [*Brassica juncea* (L.) Czernj and Coss.]. The experiment was laid out in split-plot design with three replications in cropping system mode. The main plot treatments consisted of four moisture conservation practices adopted in *kharif* season crop viz. ridges and furrows (RF), RF + crop residue (CR) 4 tonnes/ha, RF + CR 2 tonnes/ha + vesicular arbuscular mycorrhiza (VAM) and flat sowing (FS) and in sub plots; five zero tillage management techniques, viz. zero tillage (ZT), ZT + seed priming, ZT + CR 4 tonnes/ha, ZT + CR 2 tonnes/ha + Hydrogel and conventional tillage (CT) were executed in mustard. Results revealed that moisture conservation technique, RF + CR 4 tonnes/ha in main plot and tillage management practice ZT + CR 4 tonnes/ha in sub plot recorded significantly superior growth parameters, physiological indices, yield attributes and yield values over rest of the treatments. Sowing in furrows under RF + CR 4 tonnes/ha recorded highest values for seeds/siliqua and siliqua length to the tune of 13.16 and 4.17 cm, seed yield (2.12 tonnes/ha) and stover yield (7.46 tonnes/ha), respectively. Furthermore under RF + CR 4 tonnes/ha treatment registered significantly higher WUE (21.63 kg/ha/mm) as well as maximum N, P and K uptake values of 102.7, 21.02 and 97.15 kg/ha, respectively. Highest net returns of ₹ 54100/ha as well as B:C ratio (2.88) were obtained under RF + CR 4 tonnes/ha. In sub-plots, ZT + CR 4 tonnes/ha gave significantly higher values of siliqua/plant, seeds/siliqua and siliqua length to the tune of 342, 13.18 and 4.05 cm, respectively. ZT + CR 4 tonnes/ha recorded maximum seed yield (2.05 tonnes/ha) closely followed by ZT + CR 2 tonnes/ha + Hydrogel (1.94 tonnes/ha) and both the treatments were statistically at par. Water use efficiency under ZT sowing with CR 4 tonnes/ha and ZT + CR 2 tonnes/ha + Hydrogel, gave statistically at par values of 20.93 and 19.72 kg/ha/mm, respectively. In spite of higher cost of cultivation, significantly maximum net returns (₹ 49500/ha) were obtained under ZT + CR 4 tonnes/ha. Thus on the basis research findings, it can be established that under rainfed conditions after *kharif* crop harvest planting of Indian mustard can be done in left over furrows without any tillage with application of *ex-situ* CR 4 tonnes/ha or with CR 2 tonnes/ha + Hydrogel to save time, reduce cost and capitalize of residual moisture.

Key words: *Ex-situ* residue, Hydrogel, Mustard, Ridge and furrow, Zero tillage

India has about 141.5 Mha net sown area, out of which 80 Mha (58%) is rainfed. It contributes 40% of India's foodgrains production and support 66% livestock population (CRIDA 2015). Likewise, 40% of the population depends on rainfed agriculture and its performance is critical to enhance production, achieve and sustain high agricultural growth in years to come. Indian mustard [*Brassica juncea* (L.) Czernj and Coss.] is an important

crop of rainfed areas. It account for 23% of the total oilseeds area and 25% of the total oilseeds production in the country (DAC 2016). Mostly mustard is cultivated for edible oils but also possess varied uses as condiment, spices, leafy vegetable and fodder for livestock. However its productivity in India is far below than other countries. Of the several reasons, moisture stress is the most important one because it is generally grown under rainfed conditions. An important effect of water deficit is on nutrient absorption. Moisture stress interferences in nutrient uptake and uploading mechanism leading to reduction in transpirational flow (Garg 2003).

Tillage operations strongly influence the soil properties. It is important to apply appropriate tillage practices to avoid the degradation of soil structure, maintain crop yield as well as ecosystem stability. In recent years, interest of farmers in conservation tillage has increased because of escalation

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of capital and production costs in conventional agriculture system. Use of crop residue (CR) as mulch is a viable approach to retain soil moisture and nutrients under such situations. Crop residues have competing uses like fodder in rainfed areas because of dominance of livestock, further more extra costs are also incurred in their application. Therefore, it is necessary that a suitable amount of CR should be applied to enhance crop productivity in a cost-effective manner. Evidences suggest that optimization of tillage with residue could be a key factor for achieving high remuneration as well as productive soil health.

In rainfed area, all the rainfall received is not available for the crops, as a significant part is lost as runoff and evaporation. Hence concentrated efforts are needed to develop moisture conservation practices to mitigate the water stress and prolong its availability to crop plants. The risk factor can be minimized through *in-situ* moisture conservation, suitable tillage practice, selection of suitable crops and their varieties (Rathore *et al.* 2010). Keeping all these facts in consideration, the present investigation was carried out with the objective to study the effect of moisture enhancing practices on performance of mustard under conservation agriculture (zero tillage) system in rainfed conditions.

MATERIALS AND METHODS

The field experiment was carried out at the Research Farm of ICAR-Indian Agricultural Research Institute, New Delhi during the *rabi* seasons of 2014-15 and 2015-16. The experimental site was situated at 28°38' 23" N Latitude, 77°09' 27" E Longitude and at an altitude of 228.6 m above mean sea level in a semi-arid subtropical climatic belt. The area is characterized by extreme temperatures, where the annual maximum temperature goes up to as high as 45°C in summer, whereas the minimum temperature dips to as low as 0-1°C in winter. Summers are long (early April-June) with the monsoon setting in between June end to July. The soil at experiment site was sandy loam in texture and slightly alkaline in reaction (pH 7.7) having low organic carbon (4.6 g/kg), available nitrogen (135 kg/ha) and medium in available P (13.2 kg/ha) and K (180 kg/ha).

The main plot treatments consisted of four moisture conservation practices, *viz.* ridges and furrows (RF) sowing, RF + *ex-situ* crop residue (CR) (4 tonnes/ha), RF + CR (2 tonnes/ha) + VAM and flat sowing (FS) and five zero tillage management techniques in sub plots; Zero tillage (ZT), ZT + seed priming (SP), ZT + CR (4 tonnes/ha), ZT + CR (2 tonnes/ha) + Hydrogel and conventional tillage (CT) under cropping system mode where the crop residue of previous crop was used in mustard crop. In CT, field was prepared with a disc plough followed by two pass of a disc harrow and planking in the last to have a uniform seed bed of fine tilth. No tillage operation was carried out in ZT plot except for mustard sowing. At sowing time, VAM treatment @ 5 kg/ha was done for moisture conservation. Seed priming with 0.2% KMNO₄ was done for moisture conservation at the time of sowing in respective treatments. Crop residues

of previous season maize were applied by spreading the material uniformly on the field just after sowing. Pusa mustard 28 was sown with a row spacing of 60 cm in furrows. Uniform dose of N, P₂O₅ and K₂O @ 80:40:30 kg/ha were applied to all the treatments. Entire phosphorus and potassium were applied as basal dose at the time of sowing, whereas N was applied in two equal split through urea. In ZT plots, weeds were managed by Pendimethalin @ 0.75 kg a.i./ha as pre-emergence application. Plant population was maintained by thinning at 15-20 days after emergence.

During *rabi* season, the total precipitation received was 227.8 and 22.0 mm in first and second year, respectively. A good amount of rainfall during mid-December and January led to better growth of mustard in first year but crop faced stress in second year during same months. The moisture content in soil was measured from 0-30 depth by gravimetric method. The evapotranspiration from each treatment plot was calculated from the soil moisture difference between beginning and end of the cropping season to which the effective rainfall of the period was added. Effective rainfall was calculated by USDA, Soil Conservation Service method in CROPWAT 8.0 (model developed by FAO).

The total consumptive use was then calculated by using the equation:

Seasonal consumptive use (mm) = Soil moisture contribution + Effective rainfall

$$\text{Soil moisture contribution (mm)} = B_i - E_j$$

where, B_i = total profile moisture content at the time of sowing; E_j = total profile moisture content at the time of harvesting.

Water-use efficiency (WUE) of crop was worked out from the seasonal crop consumptive use (~ET) of water as illustrated by following formula:

$$\text{Water-use efficiency (kg/ha-mm)} = \frac{\text{Grain yield (kg/ha)}}{\text{Consumptive use (mm)}}$$

Canopy temperature depression (CTD) was measured with the help of infrared thermometer inside the plant canopy and compared with ambient temperature. For SPAD values, leaf chlorophyll content of the uppermost fully expanded leaves was assessed with a portable chlorophyll meter and expressed in arbitrary absorbance (or SPAD) values. All chlorophyll meter readings were taken midway between the stalk and the tip of the leaf. A hand held GreenSeeker™ Optical sensor unit was used to measure Normalized Difference Vegetation Index (NDVI). The device measures the fraction of the emitted light in the sensed area that is returned to the sensor (reflectance). These fractions are used within the sensor to calculate the NDVI according to the following formula:

$$\text{NDVI} = \frac{\text{NIR} - \text{VIS}}{\text{NIR} + \text{VIS}}$$

where, NIR is near infra-red radiation and VIS is visible red radiation.

Seed and stalk yield was expressed at 8 and 15% moisture content, respectively. Total nutrient uptake

(N, P and K) by mustard crop at harvesting stage under different treatments was estimated using nutrient content in seed, stalk and yield. The economics was computed using prevailing prices of inputs and outputs. Benefit cost (B:C) ratio was calculated by dividing net returns by cost of cultivation. Pooled mean data of two years (2014-15 and 2015-16) obtained from various observations was statistically analyzed in split-plot design (Gomez and Gomez 2010). The differences between the treatment means were tested at critical difference (CD) value at 5% level of probability.

RESULTS AND DISCUSSION

Growth parameters

The treatments of moisture conservation techniques in main plots and tillage management practices in sub-plots brought significant effect on different growth parameters, viz. plant height, dry matter accumulation (DMA) and leaf area index (LAI) of mustard (Table 1). In main plot, tallest plants (165 cm) and maximum DMA (82.5 g/plant) were recorded in treatment RF + CR (4 tonnes/ha). The values were significantly high with an edge of 10% and 17% in comparison to RF and FS, respectively. On similar lines, at 90 DAS, RF + CR (4 tonnes/ha) gave maximum LAI (3.15) which was statistically superior over rest of the treatments but at par to RF + CR (2 tonnes/ha) + VAM (2.96). The enhancement in moisture availability to plants resulted in cell turgidity and eventually high meristematic activity. This lead to more foliage development, greater photosynthetic activity and consequently higher growth and development. (Ravisankar *et al.* 2014). Among sub-plot treatments, ZT +

CR (4 tonnes/ha) and ZT + CR (2 tonnes/ha) + Hydrogel, respectively gave at par but significantly higher values of plant height (161 and 156 cm), DMA (82.3 and 81.6 g/plant) and LAI (3.07 and 2.96) in comparison to sole ZT, ZT + seed priming and CT treatments, respectively. It is to underscore that without residue ZT and CT were at par for most of the growth parameters. Zero tillage along with residue application enhances the nutrient supply through decomposition of organic residue coupled with favorable moisture condition creates favorable environment for plant growth and development (Saha and Ghosh 2012).

Physiological indices

Canopy temperature depression (CTD) indicates the canopy coolness of plant in comparison to ambient temperature. CTD trend at 30, 60 and 90 DAS shows (Fig 1) maximum values at 90 DAS followed by 30 DAS with a marginal dip at 60 DAS. Residue based moisture conserving treatment in main plot, RF + CR (4 tonnes/ha) recorded significantly higher values 3.85, 3.07 and 4.62°C at 30, 60 and 90 DAS, respectively. RF and RF+ CR (2 tonnes/ha)+ VAM were at par but significantly higher over FS treatment which recorded lowest values at all the stages. Under sub-plot treatments, ZT + CR (4 tonnes/ha) maintained edge over other treatments by recording maximum values of 3.74, 3.0 and 4.57°C at 30, 60 and 90 DAS, respectively. The reason for higher CTD values in residue based treatments is attributed to lush plant growth obtained through higher transpiration. Higher transpiration creating canopy coolness as higher CTD values than of ambient temperature is also explained by Niwas and Khichar (2016) in their work on mustard.

Table 1 Effect of moisture conservation techniques and zero tillage management practices on growth parameters and yield attributes of Indian mustard (mean of 2 years)

Treatment	Plant height at harvest (cm)	DMA at harvest (g/plant)	LAI at 90 DAS	Siliquae/plant	Seeds/siliqua	Siliquae length (cm)	1000 seed wt. (g)
<i>Moisture conservation techniques</i>							
Ridge and furrows (RF)	150	74.6	2.62	275	12.71	3.63	4.63
RF + 4 tonnes/ha crop residue (CR)	165	82.5	3.15	345	13.16	4.17	4.75
RF + 2 tonnes/ha CR + VAM	153	79.3	2.96	313	13.03	3.81	4.61
Flat sowing	141	70.9	2.45	240	12.58	2.98	4.51
SEm±	2.43	0.8	0.07	6.2	0.12	0.06	0.05
LSD (P=0.05)	8.40	2.7	0.24	NS	0.43	0.21	NS
<i>Zero tillage management</i>							
Zero tillage	149	73.7	2.70	275	12.79	3.50	4.57
ZT + Seed priming	149	74.6	2.75	285	12.68	3.64	4.66
ZT + 4 tonnes/ha crop residue (CR)	161	82.3	3.07	342	13.18	4.05	4.71
ZT + 2 tonnes/ha CR + Hydrogel	156	81.6	2.96	316	13.13	3.88	4.71
Conventional tillage	146	72.0	2.49	248	12.57	3.18	4.49
SEm±	3.01	0.9	0.05	4.7	0.15	0.09	0.06
LSD (P=0.05)	8.68	2.5	0.14	13.6	0.43	0.27	NS

DMA-Dry matter accumulation, LAI- leaf area index, CTD- canopy temperature depression, DAS-days after sowing, VAM- vesicular arbuscular mycorrhiza

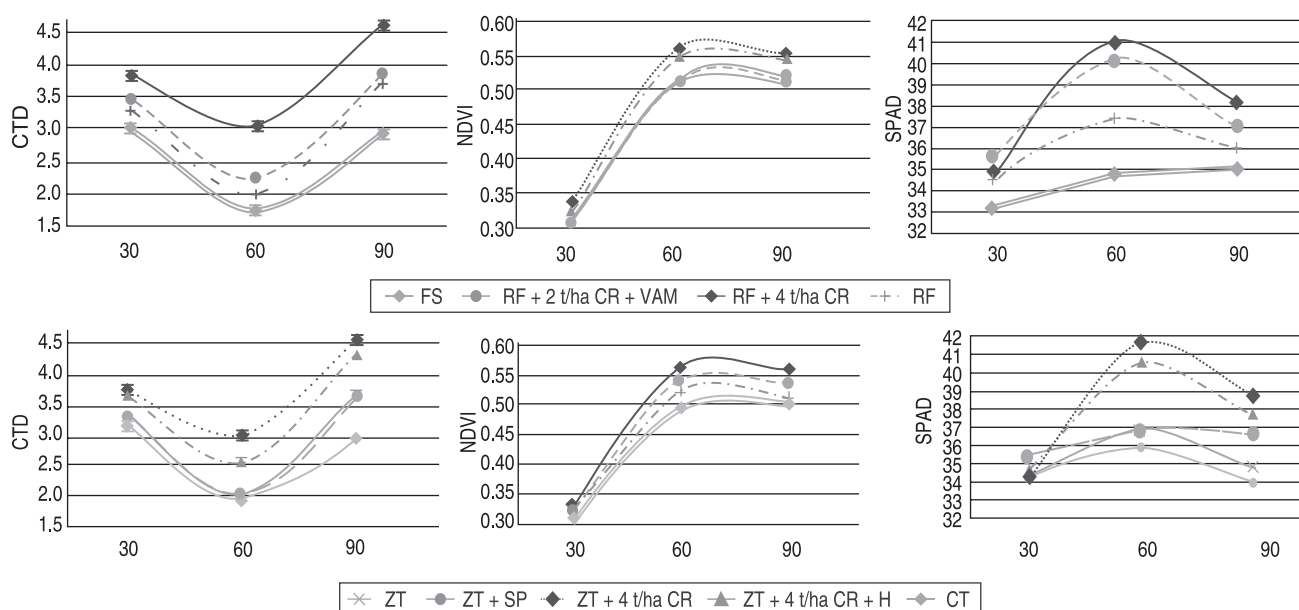


Fig 1 Effect of moisture conservation measures and zero tillage practices on different physiological indices of mustard

The SPAD values measured at 30, 60 and 90 DAS were significantly influenced by different treatments. The graph plotted showed the normal curve pattern with maximum values at 60 DAS. Among main plot treatments, steadily RF + CR (4 tonnes/ha) registered significantly higher values of 34.84, 41.02 and 38.12, at 30, 60 and 90 DAS, respectively. The mentioned values were at par with another residue based treatment RF + CR (2 tonnes/ha) + VAM (35.61, 40.15 and 37.08, respectively). Higher SPAD values in main plot treatment can be attributed to higher chlorophyll content in treatment having good growth indices, viz. LAI and DMA. Among sub-plot treatments, ZT + CR (4 tonnes/ha) and ZT + CR (2 tonnes/ha) + Hydrogel were significantly superior over other non-residue based ZT practices. Constantly higher SPAD values under residue based treatments indicates higher chlorophyll under higher moisture conserved treatment plots (Chouksey *et al.* 2014).

Leaf reflectance measured through NDVI gave statistically at par values for different main-plot treatments indicating uniformity in leaf area expansion in different main plots treatments. At 30 DAS, the values were non-significant both in main and subplots. The NDVI values trend over different stages shows peak values at 60 DAS and thereafter plateau was observed. Both the residue based treatments of main-plot (RF + CR 4 tonnes/ha) and sub-plot (ZT + CR 4 tonnes/ha) maintained their superiority at all the growth stages with values of 0.496 and 0.553, respectively at 60 DAS.

Nutrient uptake

Sowing in treatment RF with 4 tonnes/ha CR registered significantly superior N, P and K uptakes values to the tune of 102.7, 21.02 and 97.15 kg/ha, respectively (Fig 2). In comparison to FS, the mentioned values were 40.5, 42.5 and 47.3% higher for N, P and K, respectively. As nutrient

uptake is the function of nutrient concentration and biomass production, significant increase under residue treatment enhancing the total uptake; aptly justifies the reasoning. Parihar *et al.* (2010) and Pathak *et al.* (2015) reported higher nutrient uptake in residue applied sowing treatments in Indian mustard. In sub-plots, ZT + CR 4 tonnes/ha treatment got maximum uptake values of 99.29, 20.54 and 94.93 kg/ha for N, P and K, respectively which was 40.5, 42.5 and 47.3% higher over CT. The mentioned values were closely followed by ZT + CR (2 tonnes/ha) + Hydrogel uptake values. Zero tillage and ZT + seed priming treatments were statistically at par but gave significantly higher values in comparison to CT. Similar findings are reported by Singh and Singh (2014) in their work on mustard in eastern UP.

Yield attributes

Moisture conservation techniques in main plots and ZT management practices in sub-plots significantly influenced the yield attributes while siliqua/plant (in main plots) and 1000-seed weight remained unchanged (Table 1). Both seeds/siliqua and siliqua length recorded maximum values of 13.16 and 4.17 cm, respectively under RF + CR (4 tonnes/ha) treatment. Minimum values were recorded in FS for all the yield attributing parameters. Better values in RF planting is attributed to combined application of *in-situ* residue and moisture availability leading to conducive effects for soil mineralization (Regar *et al.* 2009). In sub-plots, ZT + CR (4 tonnes/ha) gave significantly higher values of siliqua/plant, seeds/siliqua and siliqua length to the tune of 342, 13.18 and 4.05 cm, respectively. This was 38.2, 5.0 and 27% higher in comparison to CT, which recorded minimum values for the mentioned parameters. Zero tillage had favourable effect on mustard crop as it conserved more moisture in the soil profile during early growth period. Subsequent release of conserved soil moisture

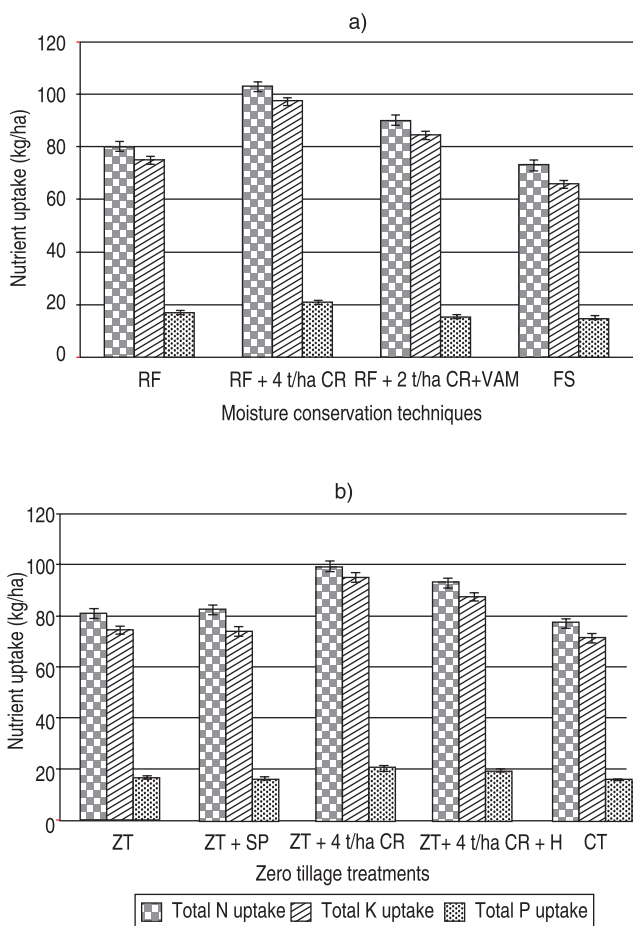


Fig 2 Effect of a) moisture conservation techniques and b) zero tillage practices on nutrient uptake of mustard

regulates plant water status, soil temperature, lowers soil mechanical resistance, leading to better root growth and higher seed yield as reported by Mondal *et al.* (2008). The 1000 seed weight values were non-significant during the study. Being a genetically intact parameter change in test weight due to environment effects is rare.

Yield

Seed yield of mustard was significantly influenced by different treatments (Table 2). In main plots, maximum seed and stalk yield were obtained under RF + CR (4 tonnes/ha), which remained significantly higher than rest of the treatments. Crop residue at 4 tonnes/ha in RF treatment produced numerically higher seed yield (2.12 tonnes/ha) and stover yield (7.46 tonnes/ha). Significantly increased seed yield by 11.5, 23.1 and 35.8% was obtained in RF + CR (4 tonnes/ha) over sole RF, RF + CR (2 tonnes/ha) + VAM and FS, respectively. This increase can be attributed to rapid decomposition of organic residue that helped in greater availability of nutrients, which led to increase in growth and yield attributes and finally the yield as explained by Sharma *et al.* (2008), Thierfelder and Wall (2012). For stalk yield too, RF + CR (4 tonnes/ha) gave significantly higher values of 7.46 tonnes/ha which was 11.5, 23.7 and 40.1% higher over RF, RF + CR (2 tonnes/ha) + VAM and FS treatments, respectively.

Under sub-plot treatments, ZT + CR (4 tonnes/ha) recorded maximum seed yield (2.05 tonnes/ha) which was closely followed by ZT + CR (2 tonnes/ha) + Hydrogel (1.94 tonnes/ha) but both the treatments were statistically at par. The maximum seed yield obtained under ZT + CR (4 tonnes/ha) was 24% higher over the CT. On similar lines, ZT + CR

Table 2 Effect of moisture conservation techniques and zero tillage management practices on yield, water use and economics of Indian mustard (mean of 2 years)

Treatment	Seed yield (tonnes/ha)	Stalk yield (tonnes/ha)	Harvest index (%)	WUE (kg/ha/mm)	COC (× 10 ³ ₹/ha)	Net returns (× 10 ³ ₹/ha)	B:C ratio
<i>Moisture conservation techniques</i>							
Ridge and furrows (RF)	1.72	6.03	22.19	17.30	19.16	40.2	2.11
RF + 4 tonnes/ha crop residue (CR)	2.12	7.46	22.33	21.63	19.16	54.1	2.88
RF + 2 tonnes/ha CR + VAM	1.90	6.51	22.58	19.12	19.16	46.1	2.45
Flat sowing	1.56	5.33	22.80	15.65	19.16	34.7	1.83
SEm±	0.04	0.11	0.45	0.41		1.31	0.07
LSD (P=0.05)	0.14	0.38	NS	1.43		4.52	0.23
<i>Zero tillage management</i>							
Zero tillage	1.72	5.90	22.68	17.32	16.78	42.5	2.55
ZT + Seed priming	1.76	5.85	23.21	17.77	17.04	43.4	2.56
ZT + 4 tonnes/ha crop residue (CR)	2.05	7.32	22.05	20.93	21.46	49.5	2.32
ZT + 2 tonnes/ha CR + Hydrogel	1.94	6.85	22.16	19.72	20.46	46.7	2.30
Conventional tillage	1.65	5.73	22.27	16.37	20.05	36.8	1.85
SEm±	0.05	0.11	0.62	0.51		1.45	0.08
LSD (P=0.05)	0.14	0.32	NS	1.47		4.18	0.22

WUE-Water use efficiency, COC-cost of cultivation

(4 tonnes/ha) knocked highest stover yield of 7.32 tonnes/ha while minimum (5.73 tonnes/ha) was obtained in CT. The effectiveness of thick residue (4 tonnes/ha) was observed in ZT system. It is likely that applying 4 tonnes/ha CR in ZT have assisted the soil with the same benefits in terms of developing favourable soil surface. These results were in close conformity with Singh *et al.* (2014). However, either of the treatment failed to bring any change in harvest index.

Water-use efficiency

Mustards owing under treatment RF + CR (4 tonnes/ha) recorded significantly higher WUE (21.63 kg/ha/mm) followed by RF + CR (2 tonnes/ha) +VAM (19.12 kg/ha/mm) (Table 2). Maximum WUE was 13.12% and 38.21% higher over RF + CR (2 tonnes/ha) +VAM and FS, respectively. Lowest value recorded in FS (15.65 kg/ha/mm) was at par with of sole RF. As explicated by Hati *et al.* (2001), the reduction in consumptive use of water by residue application brings significant improvement in WUE. In sub-plots, ZT+ CR (4 tonnes/ha) and ZT + CR (2 tonnes/ha) + Hydrogel, gave statistically at par values of 20.93 and 19.72 kg/ha/mm, respectively. In comparison to CT, the treatments recorded an average of 27% higher WUE. The values received in residue based treatments were significantly higher over the remaining three treatments. Greater soil moisture retention and moderated soil thermal regime under residue applied tillage practices resulted in higher seed yield and lowering of water use leading to increased WUE (Kumar *et al.* 2011).

Economics

Implications of different treatments on economics of the mustard cultivation is elucidated with cost of cultivation, net returns and B: C ratio (Table 2). As treatments were imposed in cropping system mode, the cost of cultivation in main plots was alike but net returns and B:C ratio were significantly influenced. Maximum net returns of ₹ 54100/ha as well as B:C ratio (2.88) were obtained under RF + CR (4 tonnes/ha). Flat sowing treatment gave lowest economics returns in main plot. The assenting effects of residue retention witnessed on productivity are translated more favourably in economics. Higher yields with minimal cost of cultivation resulted in maximum net returns and B: C ratio in RF with residue application. Similar effects were observed by Hariom *et al.* (2013) in Mustard. In sub-plots, in spite of higher cost of cultivation, significantly higher net returns (₹ 49500/ha) were obtained under ZT + CR (4 tonnes/ha). Both the residue based ZT treatments were at par and significantly higher over CT recording lowest net returns (₹ 36800/ha). However for B:C ratio, ZT + seed priming recorded maximum value of 2.56. While the best treatment ZT + CR (4 tonnes/ha) gave B:C ratio of 2.32. Higher net returns under ZT with 4 tonnes/ha crop residue might be due to more earnings from higher yield in comparison to cost involved under other treatment. Good net returns under conservation tillage in mustard had also been reported by Krishna and Veettil (2014).

On the basis of two years' study, it can be concluded that under rainfed conditions after *kharif* crop, sowing of Indian mustard can be done in left over furrows without any tillage but with application of residues of 4 tonnes/ha CR or with 2 tonnes/ha CR + Hydrogel to achieve time saving, cost reduction and capitalization of residual moisture. The study emphasizes about the effectiveness of residue application as mulch for moisture conservation in rainfed conditions as well as conservation tillage. Therefore, large scale adoption of the best conservation treatments i.e. mustard sowing with ZT with 4 tonnes/ha CR in the semi-arid track of India will be a practical solution for improving the yield as well as soil quality.

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