Original Research

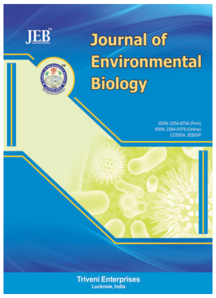
Journal Home page : www.jeb.co.in ★ E-mail : editor@jeb.co.in

Journal of Environmental Biology

JEB™

p-ISSN: 0254-8704
e-ISSN: 2394-0379
CODEN: JEBIDP

DOI : http://doi.org/10.22438/jeb/39/4/MRN-549



Resource conservation practices in maize-mustard cropping system: Impact on energy, soil carbon and nutrient dynamics

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Key words

Carbon sequestration
Energy indices
Hydrogel
Semi-arid region
Zero tillage

Publication Info

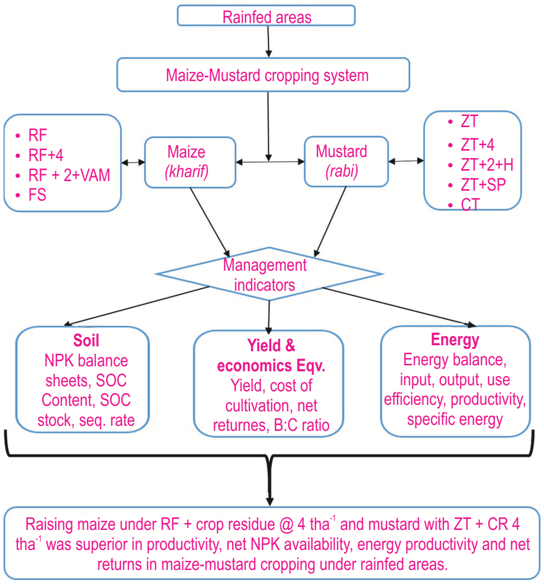
Paper received : 24.12.2016
Revised received : 03.06.2017
Accepted : 01.11.2017

Abstract

Aim : Ensuring incessant availability of water and nutrient is an arduous task particularly in rainfed areas. Hence, certain resource conservation measures are needed in those areas for increasing productivity under new emerging cropping systems. Impact of different resource and moisture conservation practices on yield, economics, energy and nutrient dynamics was studied on maize-mustard cropping system in semi-arid region of India.

Methodology : The experiment was laid out in split-plot design with three replications. The main plot treatments consisted of four soil moisture conservation practices in *kharif* season maize *i.e.* ridges and furrows (RF), RF + crop residue (CR) @ 4 t ha^{-1}, RF + CR @ 2 tha^{-1} + VAM and flat sowing (FS). Five zero tillage (ZT) management techniques in *rabi* season mustard *i.e.* ZT, ZT + seed priming, ZT + CR @ 4 t ha^{-1}, ZT + CR @ 2 t ha^{-1} + Hydrogel and conventional tillage (CT) were undertaken in sub plots in mustard under cropping system mode.

Results : Planting of maize and mustard under RF with 4 tha^{-1} crop residue recorded significantly higher system productivity during 2014-15 and 2015-16 over other treatments. Among the ZT management practices, ZT + CR 4 t ha^{-1} registered maximum MEY in first and second year, respectively. After 2 years of study, maximum SOC sequestration rate (3.48 t ha^{-1}yr^{-1}) was observed in RF + CR 2 t ha^{-1} + VAM followed by control (FS, 3.40 t ha^{-1}yr^{-1}) treatment. Among the sub-plot treatments, ZT + CR 2 tha^{-1} + hydrogel recorded maximum values of SOC sequestration rate to the tune of 3.42 t ha^{-1}yr^{-1}, respectively. Nutrient balance studies showed, RF + CR 4 t ha^{-1} having positive N balance (75 kg ha^{-1}) whereas under sub-plot treatments N balance varied from 113-154 kg ha^{-1} with maximum N balance obtained in CT.



Interpretation : Raising maize under RF moisture conservation technique with application of crop residue @ 4 t ha^{-1} and mustard with ZT + CR 4 t ha^{-1} were found superior in terms of overall productivity in maize-mustard cropping system, which also fetched maximum net returns. Higher output energy was obtained in above mentioned treatments, while energy-use efficiency and energy productivity was higher under control treatments.

Introduction

India possesses about 141.58 million hectare net sown area, out of which 58% is rainfed. It contributes 40% to country's food grain production and support 66% livestock population. 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 (CRIDA, 2015). In *rainfed* areas across India, maize–mustard cropping system is the promising one. Maize-mustard cropping system is predominant in sub-tropical hill ecosystems of north-eastern region (Munda *et al*., 1999, Panwar, 2008), south-eastern Rajasthan (Kumpawat, 2004) and Jammu region (Nandan *et al*., 2013). Both the crops of this system are nutrient-exhaustive and deplete soil nutrients and moisture extensively. Poor recycling of resources leads to emergence of multiple deficiencies in this cropping system (Das *et al*., 2010).

Conservation tillage and residue retention (mulching) has been found very effective in sustaining rainfed farming (Saha *et al*., 2010). Management practices such as conservation tillage (Lal *et al*., 1999) and soil moisture conservation measures can improve the SOC stock and net carbon sink potential which is the core of soil health. Keeping in view the finite carbon sink capacity of soil (Chung *et al*., 2010), extensively cultivated lands, if put under zero tillage and also other soil moisture conservation measures, can act as potential carbon sinks. Soil management practices like application of manures, fertilizers, irrigation of semi-arid and marginal lands for crop production can increase the carbon status (Schlesinger, 2000).

Some work has been done on nutrient management aspect of maize-mustard cropping system but effect of moisture conservation practices and tillage aspects with their residual effects has not been explored enough. Keeping these facts in view the present investigation was carried out with the objective to study the effect of soil moisture enhancing practices and conservation tillage on performance of rainfed maize-mustard cropping system.

Materials and Methods

Study area : A field experiment was conducted at the Research Farm of ICAR-Indian Agricultural Research Institute, New Delhi during 2014-16. The experimental site was situated at an altitude of 228.6 m above msl in a semi-arid subtropical climatic belt. The total precipitation received during *kharif* (monsoon) season of 2014 and 2015 was 395.4 and 710 mm, while for rabi (winter) season it was 227.8 and 22.0 mm in first and second year, respectively. The soil was sandy loam in texture and slightly alkaline in reaction (pH 7.7).

Treatments and layout : The experiment was laid out in split-plot design with three replications. The main plot treatments consisted of four moisture conservation practices in *kharif* season maize *viz*. ridges and furrows (RF), RF + crop residue (CR) @ 4 t ha^{-1}, RF + CR @ 2 t ha^{-1} + VAM, and flat sowing (FS). Five zero tillage (ZT) management techniques in rabi season mustard *viz*. ZT, ZT + seed priming, ZT + CR @ 4 t ha^{-1}, ZT + CR @ 2 t ha^{-1} + Hydrogel and conventional tillage (CT) in sub plots in mustard under cropping system mode.

Cultural operations : Under CT, field was prepared with a disc plough followed by two pass of 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 mustard sowing. Crop residues of both the crops were applied by spreading the material uniformly on the field just after sowing. Maize variety 'Pusa composite 3' and 'Pusa mustard 28' was sown with a spacing of 60 cm. In ZT plots weeds were managed by Glyphosate @ 2.0 l ha^{-1} 10 days before sowing and Pendimethalin @ 0.75 kg a.i. ha^{-1} as pre-emergence application.

Data and sample analysis : In soil samples, SOC, N, P and K were estimated by the following methods : Walkley and Black (Jackson, 1973), Modified Kjeldahl (Subbiah and Asija, 1956), Olsen *et al*. (1954) and Flame photometer (Jackson, 1958), respectively. On the basis of primary data (SOC and BD values) SOC stock, build-up rate and sequestration rate was calculated (Lenka *et al*., 2013). For estimation of energy, inputs and outputs for each item and agronomic practices followed (expressed in MJ ha^{-1}), energy equivalents were adopted from various available literature (Devasenapathy *et al*., 2009; Azarpour, 2012). Net energy, energy-use efficiency and energy productivity were calculated as suggested by Mittal and Dhawan (1988) and Mandal *et al*. (2015). Mean data of two years was statistically analyzed in split-plot design using the technique of analysis of variance with appropriate least significant difference (LSD) value at 5% level of probability (Gomez and Gomez, 2010).

Results and Discussion

The productivity of maize–mustard cropping system on the basis of maize grain equivalent yield (MEY) as influenced by different treatments is presented in Table 1. Planting of maize and mustard under RF with 4 t ha^{-1} crop residue (CR) recorded significantly higher MEY (8.43 and 8.01 t ha^{-1}) followed by RF + CR 2 t ha^{-1} + VAM (7.56 and 7.21 t ha^{-1}) during 2014-15 and 2015-16, respectively. The increment in MEY was recorded as 25.8 and 26.0, 11.5 and 11.0, 42.1 and 37.8% over RF, RF + CR 2 t ha^{-1} + VAM and FS during 2014-15 and 2015-16, respectively. Panwar (2008) reported higher MEY under conjugation of organic and inorganic combinations in maize –mustard cropping system. Under sub-plots treatments, ZT+ CR 4 t ha^{-1} logged 11.2 and 16.3, 9.4 and 17, 11.5 and 30% higher MEY over ZT, ZT+ SP and CT in first and second year of experiment, respectively. It is evident that applying 4 t ha^{-1} CR in ZT have supported the soil in terms of developing favourable conditions for plant growth. Similar findings for MEY in maize-mustard cropping system was reported by Nandan *et al*. (2013).

Addition of residues @ 4 t ha^{-1} in RF system escalated the cost of cultivation by 4.5 and 4.8×10^3 ₹ ha^{-1} and addition of residues @ 2 t ha^{-1} with VAM by 3.4 and 3.6×10^3 tha^{-1} in first and second year, respectively (Table 1). Maximum net returns (91.9 and 88.0×10^3 ₹ ha^{-1}) as well as B:C ratios (2.13 and 1.89) were recorded in RF+CR 4 t ha^{-1} during both the years of study. Maximum cost incurred in RF+CR 4 t ha^{-1} which can be attributed to higher cost of residue, followed by RF+CR 2 t ha^{-1}+VAM treatment. Similar findings for economics are also reported by Das *et al*. (2010) for maize–mustard cropping system in Meghalaya region and Kumpawat (2004) in Bhilwara region of Rajasthan. Under sub-plots, the cost of cultivation increased with increasing levels of crop residues in ZT (38.2 and 41.2×10^3 ₹ ha^{-1}) to maximum at ZT+ CR 4 t ha^{-1} (42.7 and 46.1×10^3 ₹ ha^{-1}) during 2014-15 and 2015-16, respectively. Maximum net returns to the tune of 79.8 and 83.8×10^3 ₹ ha^{-1} were obtained in ZT + CR 4 t ha^{-1} which was closely followed by ZT+CR 2 t ha^{-1} + hydrogel (78.0 and 77.9×10^3 ₹ ha^{-1}) during first and second year of experiment, respectively, and both were statistically at par.

Energy indices directs that input energy under 2 and 4 t ha^{-1} CR was about 1.7 and 2.5 times higher than no-residue (Table 2). Energy-use efficiency under main plot treatment in RF+CR 4 tha^{-1} reduced by 63% in both the years whereas in sub-plots treatment ZT+CR 4 t ha^{-1} 82 and 64% in comparison to respective control treatments in first and second year respectively. The reason attributed is that with the application of CR under these treatments very high energy input was added. Higher gross output energy was recorded under RF with CR 4 t ha^{-1} followed by RF+CR 2 t ha^{-1}+ VAM due to higher yields obtained for both maize and mustard crops under these treatments. Significantly higher energy output was obtained in treatment ZT+CR 4 t ha^{-1} (255 and 267 GJ ha^{-1}) followed by ZT+CR 2 t ha^{-1}+ hydrogel (248 and 253 GJ ha^{-1}) in first and second year, respectively. Highest value for energy intensiveness (3.59 and 3.45 MJ $₹^{-1}$) was observed in RF+CR 4 t ha^{-1}. For sub-plots, 4.05 and 3.79 MJ $₹^{-1}$ were obtained for treatment ZT+CR 4 t ha^{-1} and minimum for CT and ZT treatments (1.73 and 1.69 MJ $₹^{-1}$) during the years 2014-15 and 2015-16, respectively.

Soil organic carbon (SOC) is an important index of soil health *vis-à-vis* crop yield. In comparison to initial SOC (4.68 g kg^{-1}), marginal improvement was observed in all the treatments except for control treatment of both main and sub-plots (Fig.1). Numerically higher and similar SOC values (4.81 g kg^{-1}) were observed in RF + CR 4 t ha^{-1} and RF + CR 2 t ha^{-1} + VAM treatment of moisture conservation practices. Whereas flat sowing (control) showed marginal dip in SOC (4.67 g kg^{-1}) over the initial values (4.68 g kg^{-1}). Decomposition rates of soil organic matter is slow under minimal tillage and residue retention practices, therefore OC content takes longer time to decompose (Gwenzi *et al*., 2009). In sub-plot treatments, CR application based treatments (ZT + CR 4 t ha^{-1} and ZT + CR 2 t ha^{-1} + hydrogel) upheld numerically higher SOC values (4.84 and 4.82 g kg^{-1}, respectively) over no-residue treatment. Higher SOC in residue plots than no-residue can be ascribed to quantity of residue (about 16 t ha^{-1} in two years) addition and process of carbon sequestration (Abdullah, 2014).

SOC stock was maximum in residue based treatments both in main and sub-plots (Fig. 1). After 2 years of study, SOC

Table 1 : Effect of different treatments on maize equivalent yield (MEY) and cropping system economics

Treatment	MEY (t ha^{-1})		Cost of cultivation (×10^3 ₹ ha^{-1})		Gross returns (×10^3 ₹ ha^{-1})		Net returns (×10^3 ₹ ha^{-1})		B:C Ratio	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
Moisture conservation technicques (Kharif)										
RF	6.70	6.36	38.7	41.8	108	108	69.6	66.1	1.80	1.58
RF+CR4 tha^{-1}	8.43	8.01	43.2	46.6	135	135	91.9	88.0	2.13	1.89
RF+CR2 tha^{-1} +VAM	7.56	7.21	42.1	45.4	121	121	79.0	75.3	1.88	1.66
FS	5.93	5.81	38.1	41.1	96	98	57.8	57.1	1.52	1.39
CD (P=0.05)	0.49	0.43	-	-	8.3	6.0	8.3	6.0	0.21	0.14
ZT management (Rabi)										
ZT	6.86	6.65	38.2	41.2	111	112	72.4	71.0	1.88	1.71
ZT+ S Priming	6.97	6.61	38.5	41.5	112	111	73.7	69.7	1.90	1.67
ZT+ CR4 tha^{-1}	7.63	7.74	42.7	46.1	123	130	79.8	83.8	1.86	1.82
ZT+ CR2 tha^{-1} + Hydrogel	7.46	7.30	41.8	45.0	120	123	78.0	77.9	1.86	1.72
CT	6.84	5.94	41.3	44.7	110	100	68.9	55.8	1.66	1.23
CD (P=0.05)	0.38	0.54	-	-	5.1	7.6	5.1	7.6	0.12	0.17

Table 2 : Effect of different treatments on energy indices of maize-mustard cropping system

Treatment	Input energy (GJ ha^{-1})		Output energy (GJ ha^{-1})		Energy balance (GJ ha^{-1})		Energy use efficiency		Energy productivity (kg GJ^{-1})		Energy intensiveness (MJ ₹$^{-1}$)		Specific energy (GJ kg^{-1})	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
Moisture cons. tchs. (Kharif-Maize)														
Ridge and furrows (RF)	32.9	34.1	225	226	192	192	8.92	8.37	263	234	1.68	1.60	15.6	17.8
RF+CR4 tha^{-1}	83.0	85.1	277	276	194	191	3.48	3.35	107	97	3.59	3.45	28.4	29.5
RF+CR2 tha^{-1} +VAM	58.6	60.1	247	245	189	185	4.61	4.40	140	130	2.69	2.57	23.3	24.7
Flat sowing	33.2	35.1	199	203	166	168	7.71	7.15	229	204	1.71	1.66	17.7	19.9
CD (P=0.05)	-	-	19.4	5.3	19.4	5.3	0.60	0.25	15.2	17.0	-	-	1.7	1.5
ZT mgt. (Rabi)														
ZT	36.5	38.1	228	231	191	193	8.00	7.76	237	222	1.70	1.68	14.0	14.9
ZT+ S Priming	36.6	38.3	229	226	193	188	8.08	7.48	243	218	1.70	1.68	13.9	15.2
ZT+ CR4 tha^{-1}	86.6	88.2	255	267	169	179	3.05	3.15	92	91	4.05	3.79	37.2	38.2
ZT+ CR2 tha^{-1} + Hydrogel	61.7	63.4	248	253	186	190	4.34	4.30	131	123	2.91	2.76	25.9	27.8
CT	38.5	40.2	226	210	188	170	7.43	6.40	221	176	1.73	1.69	15.1	18.6
CD (P=0.05)	-	-	6.2	8.2	6.2	8.2	0.27	0.22	8.9	16.6	-	-	1.2	2.0

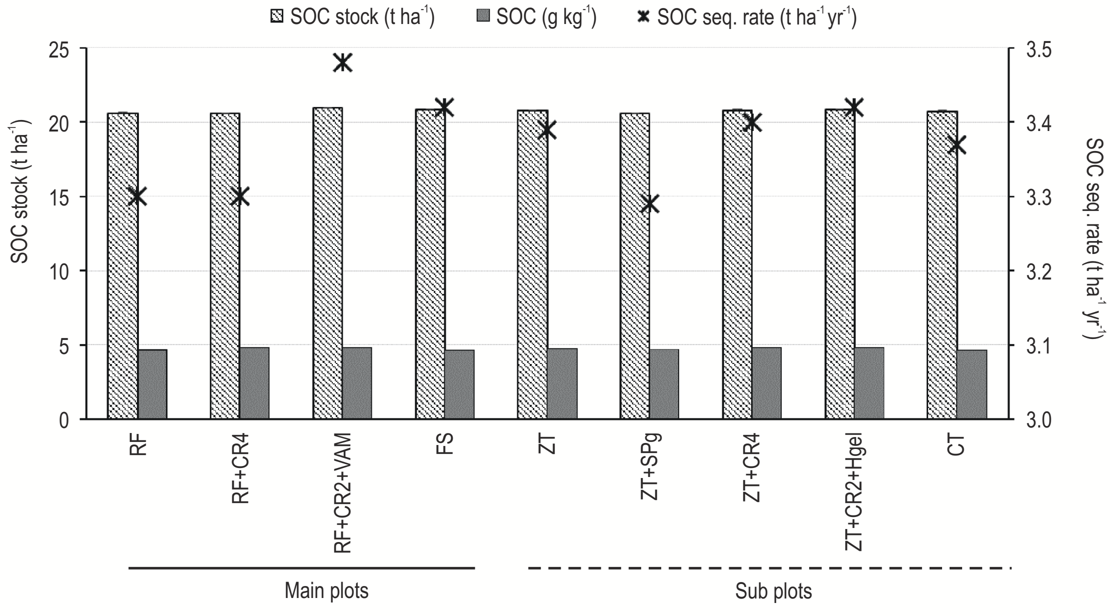


Fig. 1 : Soil organic carbon sequestration as influenced by different treatments

sequestration rate for 30 cm soil depth varied between 3.29 and 3.48 q ha^{-1}yr^{-1} and the maximum value (3.48 t ha^{-1}yr^{-1}) was observed in RF + CR 2 t ha^{-1} + VAM followed by 3.40 t ha^{-1}yr^{-1} in control (FS) treatment. Plants are the important sink of carbon and thus they possess high potential for SOC sequestration through improved management practices (Ramesh *et al*., 2015 and Parmar *et al*., 2016). Among sub-plot treatments ZT + CR 2 t ha^{-1} + hydrogel recorded maximum values of SOC sequestration rate to the tune of 3.40 t ha^{-1}yr^{-1} and 3.42 t ha^{-1}yr^{-1}, respectively. West and Post (2002) concluded that a move from CT to ZT (both with residue retention) can sequester an average 48 + 13 g C/ m^2 year^{-1}.

Table 3 : Nitrogen balance sheet influenced by different treatments in maize-mustard cropping system (at the end of 2 years crop cycle)

Treatment	Input N (kg ha^{-1})				Output N (kg ha^{-1})				
	Initial availability in soil	Fertiliser addition #	Residue addition ##	Total	Uptake	Final availability in soil	Total	Apparent balance (kg ha^{-1})	Actual change (kg ha^{-1})
	1	2	3	(1+2+3) = IN	4	5	(4+5) =OUT	(IN-OUT) = AB	(5-1) = AC
Moisture conservation technicques (Kharif-Maize)									
Ridge and furrows (RF)	135	400	13.1	548	266	136^{bc}	402	146	1
RF+CR4 tha^{-1}	135	400	33.1	568	344	149^{a}	493	75	14
RF+CR2 tha^{-1} +VAM	135	400	23.1	558	304	142^{ab}	446	112	7
Flat sowing	135	400	13.1	548	240	130^{c}	369	178	-5
ZT management (Rabi-Mustard)									
Zero tillage (ZT)	135	400	7.5	543	277	134^{b}	411	132	-1
ZT+ Seed Priming	135	400	7.5	543	277	135^{b}	413	131	---
ZT+ CR4 tha^{-1}	135	400	51.1	586	322	150^{a}	472	114	15
ZT+CR2 tha^{-1}+Hydrogel	135	400	29.3	564	306	148^{a}	454	113	10
Conventional tillage	135	400	7.5	543	260	129^{b}	389	154	-6

#Fertilizer (N) dose: (120+80), for 2 years; ##Mustard residue (2014) NPK- 0.50:0.15:1.07, Mustard residue (2015) NPK- 0.53:0.16:1.11 and ##Maize residue (2014) NPK- 0.27:0.12:1.47, Maize residue (2015) NPK- 0.29:0.15:1.43

Table 4 : Phosphorus balance sheet as influenced by different treatments in maize-mustard cropping system (at the end of 2 years crop cycle)

Treatment	Input P (kg ha^{-1})				Output P (kg ha^{-1})				
	Initial availability in soil	Fertiliser addition #	Residue addition ##	Total	Uptake	Final availability in soil	Total	Apparent balance (kg ha^{-1})	Actual change (kg ha^{-1})
	1	2	3	(1+2+3) = IN	4	5	(4+5) =OUT	(IN-OUT) = AB	(5-1) = AC
Moisture conservation technicques (Kharif-Maize)									
Ridge and furrows (RF)	13.2	200	5.16	218	56.3	12.9^{bc}	69.2	149	-0.30
RF+CR4 tha^{-1}	13.2	200	11.2	224	71.6	14.5^{a}	86.1	138	1.30
RF+CR2 tha^{-1} +VAM	13.2	200	8.16	221	62.9	13.7^{ab}	76.7	145	0.50
Flat sowing	13.2	200	5.16	218	48.9	12.1^{c}	60.9	157	-1.10
ZT management (Rabi-Mustard)									
Zero tillage (ZT)	13.2	200	2.25	215	57.2	12.5^{b}	69.7	146	-0.70
ZT+ Seed Priming	13.2	200	2.25	215	57.3	12.3^{b}	69.7	146	-0.90
ZT+ CR4 tha^{-1}	13.2	200	19.5	233	67.3	15.6^{a}	82.9	150	2.40
ZT+CR2 tha^{-1}+Hydrogel	13.2	200	10.9	224	63.9	14.5^{a}	78.4	146	1.30
Conventional tillage	13.2	200	2.25	215	53.9	11.6^{b}	65.5	150	-1.60

#Fertilizer (P) dose: (60+40), for 2 years; ##Mustard residue (2014) NPK- 0.50:0.15:1.07, Mustard residue (2015) NPK- 0.53:0.16:1.11 and ##Maize residue (2014) NPK- 0.27:0.12:1.47, Maize residue (2015) NPK- 0.29:0.15:1.43

The nutrient (N, P and K) balance sheet of the experiment describes that among different treatments RF + CR 4 t ha^{-1} registered significantly higher available N values (149 kg ha^{-1}) which was closely followed by RF+ CR 2tha^{-1} + VAM (142 kg ha^{-1}) both being statistically at par (Table 3). Residue based moisture conserving treatments gave 14.6 and 8.5% higher N availability in soil as of flat sowing (control). For N availability under different ZT management practices, ZT + CR 4 t ha^{-1} and ZT + CR 2 t ha^{-1} + hydrogel yielded statistically at par values (150 and 148 kg ha^{-1}, respectively). RF + CR 4 t ha^{-1} also showed positive N balance

(75 kg ha^{-1}) whereas FS treatment showed maximum N balance (178 kg ha^{-1}). Under sub-plots, ZT + CR 4 t ha^{-1} and ZT + CR 2 tha^{-1} + hydrogel gave low N balance of 114 and 113 kg ha^{-1}, respectively.

The initial P availability (13.2 kg ha^{-1}) in the soil was under medium class (10-25 kg ha^{-1}) (Table 4). RF + CR 4 t ha^{-1} registered significant superlative at par values to the tune of 14.5 kg ha^{-1}, which were closely followed by RF+CR 2 t ha^{-1} + VAM (13.7 kg ha^{-1}). In comparison to control (FS), an improvement of 6.8, 19.8 and 13.2% was observed in RF, RF + CR 4 t ha^{-1} and RF + CR 2 t ha^{-1}+ VAM treatments, respectively. Apparent balance showed that maximum P balance (157 kg ha^{-1}) in control treatment; whereas residue based superior treatments gave lower values (138 kg ha^{-1} for RF+CR4 t ha^{-1}). For sub-plots, ZT + CR 4 t ha^{-1} and CT gave statistically at par values (150 kg ha^{-1} for each treatment) for apparent P balance. Maximum change (1.30 kg ha^{-1}) in available P was observed in RF + CR 4 t ha^{-1} treatment in main plots and ZT + CR 4 t ha^{-1} treatment in subplots.

On a close look at K balance sheet (Table 5), it can be seen that RF and FS yielded equal values of total K input (368 kg ha^{-1}) whereas in sub-plot treatments ZT, ZT+ seed priming and CT gave equal K input values of 336 kg ha^{-1}. Main plot treatment, RF + CR 4 t ha^{-1} registered significantly higher K availability in soil (193 kg ha^{-1}) which was closely followed by RF + CR 2 t ha^{-1} + VAM (187 kg ha^{-1}) but both were statistically at par. In comparison to control, significant improvement of K availability in soil to the tune of 11.5 and 8% in RF + CR 4 t ha^{-1} and RF+CR 2 t ha^{-1} +VAM treatments, respectively was observed. In case of ZT management practices with respect to K availability; ZT + CR 4 t ha^{-1} registered maximum values (192 kg ha^{-1}) which were statistically at par to sole ZT (179 kg ha^{-1}), ZT+ Seed priming (184 kg ha^{-1}) and ZT+CR 2 t ha^{-1} + Hydrogel (190 kg ha^{-1}). Maximum positive change (12.5 kg ha^{-1}) in available K was observed in RF + CR 4 t ha^{-1} treatment in main plots, while in sub-plots it was to the tune of 11.4 kg ha^{-1} in ZT + CR 4 t ha^{-1}. Negative K availability was observed in case of flat sowing and conventional tillage.

Results indicate that nutrient availability increased with higher dose of crop residue. It proposes that changes in nutrient (NPK) availability due to tillage were limited. Whereas the beneficial effect of crop residue application were more evident because approximately 16 t ha^{-1} of residues of maize and mustard was applied in field over a period of two cropping cycles. The higher fertility in RF moisture conservation treatments along with residue brought the synergetic effects of soil water and nutrients on yield of the test crop (Gebrekidan and Uloro, 2015). Large quantities of uptake by crops, remains in the residues even after harvesting, contribute in high nutrient availability (Du Preez and Bennie, 1991). Negative values in non-residue and non-moisture conservation treatments in actual change and NPK availability indicate the inherent depletion of macronutrient of the soil.

Table 5 : Potassium balance sheet influenced by different treatments in maize-mustard cropping system (at the end of 2 years crop cycle)

Treatment	Input K (kg ha^{-1})				Output K (kg ha^{-1})				
	Initial availability in soil	**Fertiliser addition #**	**Residue addition ##**	**Total**	**Uptake**	**Final availability in soil**	**Total**	**Apparent balance (kg ha^{-1})**	**Actual change (kg ha^{-1})**
	1	**2**	**3**	**(1+2+3) = IN**	**4**	**5**	**(4+5) =OUT**	**(IN-OUT) = AB**	**(5-1) = AC**
Moisture conservation technicques (Kharif-Maize)									
Ridge and furrows (RF)	180	140	48	368	222	177^{bc}	398	-30	-3.4
RF+CR4tha^{-1}	180	140	91	411	292	193^{a}	485	-73	12.5
RF+CR2tha^{-1} +VAM	180	140	70	390	255	187^{ab}	442	-52	7.3
Flat sowing	180	140	48	368	192	173^{c}	365	3	-7.3
ZT management (Rabi-Mustard)									
Zero tillage (ZT)	180	140	16	336	227	179^{ab}	406	-70	-0.8
ZT+ Seed Priming	180	140	16	336	225	184^{a}	409	-73	3.7
ZT+ CR4tha^{-1}	180	140	176	497	275	192^{a}	467	30	11.4
ZT+CR2tha^{-1}+Hydrogel	180	140	96	416	260	190^{a}	450	-33	9.5
Conventional tillage	180	140	16	336	213	168^{b}	381	-45	-12.5

[#]Fertilizer (K) dose: (40+30), for 2 years; [##]Mustard residue (2014) NPK- 0.50:0.15:1.07, Mustard residue (2015) NPK- 0.53:0.16:1.11 and [##]Maize residue (2014) NPK- 0.27:0.12:1.47, Maize residue (2015) NPK- 0.29:0.15:1.43

In conclusion, raising maize under RF moisture conservation technique with application of crop residue @ 4 t ha^{-1} and mustard with ZT + CR 4 t ha^{-1} were found superior in terms of productivity in maize-mustard cropping system under rainfed condition fetched maximum net returns. Soil physical and chemical properties were favourably influenced under residue cover than no residue. This cropping system can be remunerative in monetary as well as soil health terms with use of crop residue and conservation based tillage.

References

Abdullah, A.S.: Minimum tillage and residue management increase soil water content, soil organic matter and canola seed yield and seed oil content in the semi-arid areas of Northern Iraq. *Soil Tillage Res*., **144**, 150–55 (2014).

Azarpour, E.: Determination of energy balance and energy indices in wheat production under watered farming in north of Iran. *ARPN J Agri. Bio. Sci*., **7**, 250–255 (2012).

Chung, H., K.J., Ngo, A.F., Plante and J. Six: Evidence for carbon saturation in a highly structured and organic matter rich soil. Soil *Sci. Soc. Am. J*., **74**, 130–138 (2010).

CRIDA. Vision 2050. ICAR-Central Research Institute for Dryland Agriculture, Santoshnagar, Hyderabad, p. 1 (2015).

Das, A., D. P., Patel, G. C. Munda and P. K. Ghosh: Effect of organic and inorganic sources of nutrients on yield, nutrient uptake and soil fertility of maize (*Zea mays*)-mustard (*Brassica campestris*) cropping system. *Ind. J. Agri. Sci*., **80**, 85–88 (2010).

Devasenapathy, P., G. Senthilkumar and P.M. Shanmugam: Energy management in crop production. *Indian J. Agron*., **54**, 80–90 (2009).

Du Preez, C.C. and A.T.P. Bennie: Concentration, accumulation and uptake rate of macro-nutrients by winter wheat under irrigation. *S. Afr. J. Plant Soil*, **8**, 31–37 (1991).

Gebrekidan, H. and Y. Uloro: Yield response of maize (*Zea mays* L.) to tied ridges and planting methods on Entisols and Vertisols of the eastern Ethiopian highlands. In abstracts: Tropical Agriculture. The University of West Indies at St. Augustine, Trinidad and Tobago **88** (2015).

Gomez, K.A. and A. A. Gomez: Statistical procedures for agricultural research, 2nd Edn., John Wiley and Sons, New York, p.704 (2010).

Gwenzi, W., J., Gotosa, S. Chakanetsa and Z. Mutema : Effects of tillage systems on soil organic carbon dynamics, structural stability and crop yields in irrigated wheat (*Triticum aestivum* L.)–cotton (*Gossypium hirsutum* L.) rotation in semi-arid Zimbabwe. *Nut. Cyc. Agroecosys*., **83**, 211–221 (2009).

Jackson, M.L.: Soil chemical analysis, Asian Publication House, New Delhi, pp. 173–195 (1958).

Jackson, M.L.: Soil chemical analysis. Prentice Hall Inc., Englewood, Cliffs, U.S.A., pp. 159–174 (1973).

Kumpawat, B.S.: Integrated nutrient management in maize mustard cropping system in southern Rajasthan. *Indian J. Agron*., **49**, 18-21 (2004).

Lal, R., R.F. Follett, J. Kimble and C.V. Cole: Managing US cropland to sequester carbon in soil. *J. Soil Water Conserv*., **54**, 374–381 (1999).

Lenka, N. K., S., Sudhishri, A., Dass, P. R., Choudhury, S., Lenka and U.S. Patnaik: Soil carbon sequestration as affected by slope aspect under restoration treatments of a degradedalfisol in the Indian sub-tropics. *Geoderma*, **204**,102–110 (2013).

Mandal, S., A. Roy, G.I. Das, R. Ramkrushna, B.C. Lal, A.K. Verma, R.K. Singh, and J. Layek: Energy efficiency and economics of rice cultivation systems under subtropical Eastern Himalaya. *En. Sus. Devlop*., **28,** 115–121 (2015).

Mittal, J.P. and K. C. Dhawan: Research manual on energy requirements in agricultural sector. ICAR, New Delhi, p. 150 (1988).

Munda, G.C., U. K. Hazarika, D.C. Saxena, R. Singh and D.P. Patel: Performance of cropping system under mid altitude rainfed dry terrace of Meghalaya. *Ind. J. Hill Farm*., **12**, 106-10 (1999).

Nandan, B., B. C. Sharma and A. Kumar: Effects of mustard-maize intercropping system on productivity of maize in moisture deficit sub-tropical areas of Jammu and Kashmir. *Schol. J. Agri. Sci*., **3**, 66-72 (2013).

Olsen, S.R., C.L., Cole, F.S. Watanabe and L.A. Dean: Estimation of available phosphorus in soil by extraction with sodium bicarbonate. USDA Circular No. 939, Washington, pp.72–75 (1954).

Panwar, A.S.: Effect of integrated nutrient management in Maize (*Zea-mays*) - Mustard cropping system (*Brasicca campestrasis* var. toria) cropping system in mid hills altitude. *Ind. J. Agri. Sci*., **78**, 27-31 (2008).

Parmar, D.K., D. R. Thakur, R.S. Jamwal and Arpana: Effect of long term organic manure application on soil properties, carbon sequestration, soil - plant carbon stock and productivity under two vegetable production systems in Himachal Pradesh. *J. Env. Bio*., **37**, 333-39 (2016).

Ramesh, T., K. M. Manjaiah, K. P. Mohopatra, K. Rajasekar and S.V. Nagchan: Assessment of soil organic carbon stocks and fractions under different agroforestry systems in subtropical hill agro ecosystems of north-east India. *Agrof.Sys*., Print ISSN 0167-4366 Online ISSN 1572-9680 (2015).

Saha, S., D. Chakraborty, A. R. Sharma, R. K. Tomar, S. Bhadraray, U. Sen, U. K. Behera, T. J. Purakayastha, R. N. Garg and N. Kalra: Effect of tillage and residue management on soil physical properties and crop productivity in maize (*Zea mays*)–Indian mustard (*Brassica juncea*) system. *Indian J. Agri. Sci*., **80**, 679–85 (2010).

Schlesinger, W.H.: Carbon sequestration in soils: Some cautions amidst optimism. *Agric. Ecosys. Environ*., **82**, 121–27 (2000).

Subbiah, B.V. and G.L.Asija: A rapid procedure for the estimation of available nitrogen in soils. *Curr. Sci*.,**25**, 259–60 (1956).

West, T.O. and W. M. Post: Soil organic carbon sequestration rates by tillage and crop rotation. *Soil Sci. Soc. Am. J*., **66**, 1930-46 (2002).