Research Article

Crop Residue Management for Sustainable Production of Maize (Zea Mays) in Dryland Ecosystem

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Abstract

A field experiment was conducted for 5 year in rainy season (Kharif) during 2012-13 to 2016-2017 at Dryland Farming Research Station, Arjia, Bhilwara to study the effect of crop residue management practices alone or with combination of FYM on seed yield of maize (Zea mays). Seed yield of maize was increased by 106.4, 96.5, 73.7, 41.4 and 34.4 % with incorporation of 5t ha^{-1}FYM+ vertical mulch of sesame straw at 10 m interval @ 5 t ha^{-1}, 5 t ha^{-1}, 5 t ha^{-1} FYM + vertical mulch of mustard straw at 10 m interval @ 5 t ha^{-1}, 10 t ha^{-1} FYM and sole surface mulch of sesame straw and mustard straw @ 5 t ha^{-1} respectively over control. Vertical mulch of sesame straw at 10 m interval @ 5 t ha-^{1} with 5 t ha-^{1} FYM increased the maize seed yield by 45.9 and 106.4% over surface mulch of sesame straw @ 5t ha^{-1} and control, respectively. Higher Benefit cost ratio (BCR) and water use efficiency with lower runoff and soil loss was registered in incorporation of sesame straw as vertical mulch @ 5 t ha^{-1} with 5 t ha^{-1} FYM as compared to rest of the practices. Results indicate that incorporation of crop residues of sesame and mustard with equal amount of FYM improved the soil organic carbon, available nitrogen and phosphorus. Incorporation of FYM 5 t ha^{-1}+ vertical mulch of sesame straw at 10 m interval @ 5 t ha^{-1} increased the field capacity of soil by 9.96 and 17.6% and had favourable effect on bulk density (7.6 and 17.24% decrease) over control and initial respectively. Soil biological properties like dehydrogenase and phosphatase & also showed higher activities due to these treatments, which are essential for sustainable production system. Incorporation of 5t ha^{-1} FYM + vertical mulch of sesame straw recorded the highest energy use efficiency and energy Productivity.

Keywords: Crop residue incorporation, Farm-yard manure, Water use efficiency, Vertical mulch, Runoff and soil loss, Energy use efficiency, dehydrogenase, phosphatase

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Introduction

Crop residues are parts of the plants left in the field after crops have been harvested and threshed. These materials at times have been regarded as waste material that require disposed but it has become increasing realized that they are important natural resources and not wastes. They recycling of crop residues have the advantage of converting the surplus farm waste into useful product for meeting nutrient requirement of crops. It also maintains the physical, chemical condition [11] and improves the overall ecological balance of the production system. Soil low in organic matter, water retention and crust formations are the major constraints for higher productivity in arid fringes. The role of organic materials is being recognized for sustainable production due to increasing cost of chemical fertilizers and to maintain soil health. Addition of crop residue in the soil is not only the important sources of nutrients for crop production but also improves soil physical and chemical properties and biological functions, if managed properly [4, 8, 14]. The crop like Indian mustard (Brassica juncea L.) and sesame are widely grown in arid and semi-arid regions due to their low water requirement and tolerance to salinity. The non-palatability of residues of these crops, their management assumes special significance because of their harness to decompose due to wide C: N ratio. Unless they are supplemented by nitrogen and phosphorus during decomposition may cause immobilization of N and P for longer period. Maize (*Zea mays* L.) is the main crop grown in the *kharif* season, especially in the Mewar Region, where rainfed maize occupies more than 80% of the total maize production areas. Poor germination and slow growth in cool spring weather are major limiting factors to early production for premium market prices. Over the years, some innovative farmers have pioneered planting patterns to make full use of rainwater, which has shown great potential to reduce the impact of the severe water limitations and increase *WUE* in rainfed agricultural regions [6] and [15]

reported that mulching increased maize yield. Hence, the present investigation was under taken to find out suitable crop residue management practices for maximizing maize production in dryland ecosystem.

Materials and Methods

A field experiment was conducted during the rainy seasons (Kharif), during the period from 2012-13 to 2016-17 at Dryland Farming Research Station, Arjia, Bhilwara to study the effect of incorporation of Farm-yard manure, crop residues of mustard and sesame during rainy season on seed yield of maize. The soil of the experimental site was sandy clay loam in texture having pH 8.15, electrical conductivity 0.43 dSm^{-1} and organic carbon content 0.26%. The field capacity and wilting point were 21.3 and 9.2% respectively. The non-replicated experiment was conducted on runoff plots adopting a gross plot size of 25 m x 7 m with 2% slope. The silt and runoff were measured with multi-slot divisors constructed at the end of plots. The runoff and soil loss were measured for each rainfall events causing runoff. The treatments comprised of, FYM @ 10t ha^{-1} (T_1), FYM @ 5t ha^{-1} (T_2), mustard straw @ 5t ha^{-1} (T_3), sesame straw @ 5t ha^{-1} (T_4), vertical mulch of mustard straw at 10 m interval @ 5t ha^{-1} (T_5), vertical mulch of sesame straw @ 5t ha^{-1} at 10 m interval (T_6), FYM@ 5t ha^{-1} + vertical mulch of mustard straw at 10 m @ 5t ha^{-1} (T_7), FYM @ 5t ha^{-1} + vertical mulch of sesame straw at 10 m interval @ 5t ha^{-1} (T_8) and Farmers practice (control) (T_9), Maize variety 'PHEM-2' was the recommended varieties for the region under dryland ecosystem was cultivated in rainy season with the recommended package of practices for the zone. Vertical mulch of sesame/mustard straw at 10m interval is applied by opening the trench at 10m interval with tractor operated single bottom disc plough. There after sesame /mustard straw was put in to trench and covered manually with soil cover. Runoff, soil loss and crop yields were recorded. Water productivity was worked out by dividing the seed yield of maize by rainfall during the crop season with runoff deduction. Economics was worked out on the average market prices. Energy input and out-put was calculated as suggested by Mittal *et al.* (1985) and energy coefficients are given in **Table 1**.

Table 1 Energy coefficients used in calculation

Item	Unit	Energy, MJ
Human labor		
Adult man	Man-hour	1.96
Women	Women hour	1.57
Animal Bullocks (medium)	Pair-hour	10.10
Diesel	Liter	56.31
Fertilizer		
N	Kg	60.60
P_2O_5	Kg	10.10
K_2O	Kg	5.60
Herbicide	Kg	120.00
Seed (maize)	Kg	14.70
Straw/Stover maize	Kg	18.00
Machinery	Kg	62.70
Herbicide	Kg	5.6

Results and Discussion

Dry Matter Production

Incorporation of 10t ha^{-1} FYM, 5t ha^{-1}FYM with vertical mulch of sesame and mustard straw at 10m interval @ 5t ha^{-1} increased dry matter production of maize by 38.5, 61.2 and 45.5 %, respectively over control (2954kg ha^{-1}). However, sole application of mustard/sesame straw either surface or vertical mulch caused higher dry matter production as compared to control (**Table 2**). [10] reported incorporation of FYM with crop residues enhanced the rate of decomposition similar results were also reported by [12]. In present investigation, crop residue + FYM and/ or FYM were incorporated in the soil with the onset of monsoon rains which allowed their decomposition during rainy season. This has led to the improved plant performance as indicated by higher rate of crop growth and yield attributes and high dry matter accumulation.

Seed Yield

Farm yard manure and crop residues incorporation at 10 t/ha^{-1} and 5t ha^{-1} increased the seed yield of maize over farmers practice during the all three years, (Table 2) Farm yard manure @ 10 t ha^{-1} increased the mean seed yield of

maize by 73.7% over control (1330kg ha^{-1}) during the study period. The magnitude of increase in mean seed yield of maize due to 5t ha^{-1} FYM + vertical mulch of sesame at 10 m interval @ 5 t ha^{-1} was 106.4 and 31.3% over control and sole application of vertical mulch of sesame at 10 m interval @ 5 t ha^{-1} respectively. Sole application of crop residues of mustard and sesame either surface or a vertical mulch @ 5t ha^{-1} and in combination of 5t ha^{-1} FYM could increased seed yield of maize over control during the period of study. Such conductive effects of these organic materials may be assigned to increased availability of nutrients in soil through mineralization (**Table 3**) and improvement in physic-chemical properties of soil and also an increase of soil enzymes such as dehydro genase and photosythate through high microbial activities (**Table 4**) [5]. Higher level of organic matter application of 5t ha^{-1} FYM with vertical mulch of sesame at 10 m interval @ 5t ha^{-1} indicate increased translocation of photosythate from source to sink which resulted in high seed yield of maize [13].

Table 2 Effect of different crop residue management practices & FYM on yield of maize and water use efficiency (2012, 2014 & 2016)

Treatments	Grain yield (kg ha^{-1})				Straw yield (kg ha^{-1})				Water use efficiency (kg/ha^{-1}mm^{-1})			
	2012	2014	2016	Mean	2012	2014	2016	Mean	2012	2014	2016	Mean
T_1	2385	2143	2403	2310	5724	5543	4640	5302	12.45	3.70	4.20	6.78
T_2	1770	1771	1971	1837	4248	5657	3960	4622	9.98	3.10	3.70	5.59
T_3	1742	1714	1826	1761	4181	5457	3440	4359	9.60	3.00	3.40	5.33
T_4	2154	1571	1917	1881	5170	4714	3634	4506	11.30	2.70	3.50	5.83
T_5	1878	1943	2071	1974	4507	5314	3588	4470	10.18	3.40	3.60	5.73
T_6	1971	2114	2186	2090	4730	5028	3771	4510	10.14	3.70	3.80	5.88
T_7	2475	1828	2614	2306	5940	6114	4657	5570	11.89	3.20	4.30	6.39
T_8	2856	2428	2914	2745	6854	6428	5223	6168	13.4	4.20	4.70	7.43
T_9	1150	1429	1411	1330	3100	5428	2954	3827	9.21	2.50	2.03	4.58

Crop failed during the year 2013 and 2015 due to longer dry spell period.

Table 3 Effect of crop residue management practices on soil fertility status after 5 years period

Treatments	Organic carbon (%)	Available N (Kg/ha^{-1})	Available P (Kg/ha^{-1})
T_1	0.59	270	40.2
T_2	0.50	239	36.8
T_3	0.51	241	37.5
T_4	0.56	249	39.8
T_5	0.53	257	38.2
T_6	0.58	259	40.5
T_7	0.73	271	41.5
T_8	0.76	290	44.5
T_9	0.41	198	30.1

Table 4 Effect of crop residue management practices on soil physical properties and enzyme activities (mean of 3 years)

Treatment	Bulk density mgm^{-3}		Field capacity (%)		Dehydro-genase	Acid phosphatage	Alkaline phosphatage
	Before	after	Before	after			
Initial	1.45	-	21.3	-	-	-	-
T_1	1.30	1.28	24.06	25.04	8.9	28.7	44.8
T_2	1.40	1.34	23.05	24.72	7.8	26.8	42.5
T_3	1.38	1.22	22.65	23.78	5.8	22.2	40.8
T_4	1.37	1.19	23.05	24.04	7.9	24.4	41.9
T_5	1.40	1.20	23.08	24.06	7.04	27.5	41.7
T_6	1.38	1.20	23.09	24.45	8.07	28.7	42.4
T_7	1.39	1.26	24.02	25.00	9.3	29.9	46.2
T_8	1.37	1.20	24.08	25.05	10.5	30.16	49.8
T_9	1.42	1.39	22.02	22.78	5.2	20.3	36.4

Runoff and Soil Loss

Incorporation of crop residues and farm yard manure reduced soil loss and runoff by 74.6 to 85.8 and 44.7 to 75.9 % over control (farmers practices) (**Table 5**). Incorporation of crop residues @ 5t ha^{-1} as a vertical mulch of mustard /sesame at 10 m interval further reduced the runoff & soil loss by 8.2 to 12.5 and 8.5 to 23.7 % over surface mulch of mustard /sesame @ 5t ha^{-1}. This might be attributed to this long slope out into several short once which reduced the velocity of runoff, consequently by more runoff water is infiltrated in to the soil and caused the least runoff and soil loss. Reduction in percent of runoff, which is turn help in situ moisture conservation, besides improvement of moisture available and crop production [1]. Incorporation of 5t ha^{-1} FYM + vertical mulch of sesame at 10 m interval @ 5t ha^{-1} in to the soil was recorded the least runoff and soil loss among all the practices. This might be attributed to that straw of sesame is spongy and decomposed earlier than mustard straw and also vertical mulch cut long slope in to several short one. Thus, more runoff water is infiltrated in to the soils, which reduced the runoff and soil loss.

Table 5 Effect of different crop residue management practices on runoff and soil loss in maize cultivation

Treatments	Runoff producing rainfall (%)				Soil loss (t/ha)			
	2012	2014	2016	Mean	2012	2014	2016	Mean
T_1	19.7	18.6	18.5	18.9	2.285	2.114	2.276	2.225
T_2	25.6	23.1	23.7	24.1	2.570	2.326	2.358	2.418
T_3	24.1	22.4	22.8	23.1	2.713	2.291	2.350	2.451
T_4	20.5	19.1	20.6	20.01	2.570	2.438	2.456	2.488
T_5	22.7	20.2	20.8	21.2	2.285	2.224	2.218	2.242
T_6	18.5	16.8	17.2	17.5	1.999	1.84	1.854	1.898
T_7	12.7	11.7	12.6	12.3	1.856	1.756	1.848	1.82
T_8	10.6	10.3	10.5	10.5	1.428	1.322	1.417	1.389
T_9	49.5	38.6	42.7	43.6	11.420	8.547	9.467	9.81

Effect on Soil Properties

Incorporation of crop residues increased organic carbon content of soil from 0.35% to 41% after 5 years of study in control (farmers practice) (Table 3). This might be due to continuous mineralization and incorporation of weeds and crop residues left in the field into the soil. The increase in organic carbon content was higher when residues were applied along with FYM @ 5t ha^{-1} as compared to sole residues. Increases in soil organic carbon with application of various organic materials was also observed by [3]. Marginal increase in organic carbon content was observed when straw was incorporating sole @ 5t h^{-1}. Incorporation of crop residues and /or FYM also increased available P content of soil over the control after five years of study Maximum content of available P was found under 5t ha^{-1} FYM with vertical mulch of sesame straw at 10 m interval @ 5t ha^{-1} followed by 5t ha^{-1} FYM with vertical mulch of mustard straw @ 10 m interval @ 5t ha^{-1} and 10 t ha^{-1} FYM. [2] ascribed the increase in available P under residues incorporation due to increase in phosphatase (both acid and alkaline) enzyme activity. Similar results were also reported by [13]. Bulk density of soil decreased due to incorporation of crop residues and/or FYM and the effect was more pronounces with 5t ha^{-1} FYM + vertical mulch of sesame straw at 10 m interval @ 5t ha^{-1} measured at 15 cm depth before sowing and after harvest of maize crop as compared to control (Table 4). Application of crop residue alone or in combination with FYM at 10t ha^{-1} had favorable effect on bulk density (4.14 to 17.24% decreased over initial value whereas, decrease in bulk density recorded minimum under control. [13] recorded decrease in bulk density and increase in field capacity of soil with incorporation of crop residues and/or FYM profound effect on field capacity of soil. The field capacity increased from 21.3 at the start of the study to 3.45% under control before sowing. It was further increased to about 13.1% before sowing and to 17.6 % after harvest of maize crop due to 5t ha^{-1} FYM + vertical mulch of sesame straw at 10 m interval @ 5t ha^{-1}. [9] observed similar results in rice- wheat crop sequence. [7] also reported decrease in bulk density and increase moisture retention due to addition of organic matter into soil. Results showed improvement in dehydrogenate and phosphatage activities with the incorporation of mustard or sesame straw/FYM over control (Table 4). Incorporation of 5t ha^{-1} FYM with vertical mulch of sesame straw at 10 m interval @ 5t ha^{-1} resulted in highest increase in phosphatase activity.

Water Use Efficiency

Incorporation of crop residue and/or FYM gave higher water use efficiency over control (Table 2). This was obtained due to improvement in soil physio-chemical properties. This led to enhancement of seed yield of maize and also reduction in runoff and soil loss (Table 5). The maximum water use efficiency (4.07 kg ha^{-1}mm) was registered in 5t ha^{-1} FYM with vertical mulch of sesame straw at 10 m interval @ 5t ha^{-1}followed by 5t ha^{-1} FYM + vertical mulch of mustard straw at 10 m interval @ 5t ha^{-1}. Sole incorporation crop residues of sesame/mustard straw as a surface and vertical mulch @ 5t ha^{-1} increased the water use efficiency by 30-38.8 and 40.3-49.5%, respectively over control.

Economics

The economics of incorporation of 5t ha^{-1} FYM with vertical mulch of sesame straw @ 5t ha^{-1} recorded the highest net return of Rs.45155/- ha^{-1} with highest benefit cost ratio of 3.03 followed by 10t ha^{-1} FYM and 5t ha^{-1} FYM with vertical mulch of mustard straw at 10 m interval @ 5t ha^{-1} (**Table 6**). While the minimum benefit cost ratio of 1.79was registered in control (Farmer's practice). Incorporation 5t ha^{-1} FYM + vertical mulch of sesame straw at 10 m interval @ 5t ha^{-1} also provide intangible benefits like improvement in soil health i.e. increase in field capacity, decrease in bulk density, higher dehydrogenize and phosphatase activities and thus, this practice stands in the first order of rank followed by 5t ha^{-1} FYM + vertical mulch of mustard straw at 10 m interval @ 5t ha^{-1} and 10t ha^{-1} FYM.

Table 6 Mean Economics of different crop residue management practices in maize cultivation

Treatments	Mean yield (kg ha^{-1})		Mean cost of cultivation (Rs ha^{-1})	Mean Gross return (Rs ha^{-1})	Mean Net return (Rs ha^{-1})	Mean B:C ratio
	Grain	Straw				
T_1	2310	5302	20755	58040	37285	2.54
T_2	1837	4622	17955	47535	29580	2.24
T_3	1761	4359	20455	47578	27123	2.06
T_4	1881	4506	17955	47487	29532	2.25
T_5	1974	4470	20455	50361	29906	2.31
T_6	2090	4510	17955	50105	32150	2.48
T_7	2306	5570	22955	59470	36515	2.45
T_8	2745	6168	20455	65610	45155	3.03
T_9	1330	3827	14245	34897	20652	1.79

Energetic

The total energy input in different crop residue management practices and FYM in maize cultivation was higher is incorporation of 5t ha^{-1} FYM with vertical mulch of sesame/mustard straw at 10m interval @ 5t ha^{-1} followed by sole vertical mulch of sesame/mustard straw at 10m interval @ 5t ha^{-1}which might be attributed to increased higher organic materials levels (**Table 7**). Incorporation of 5t ha^{-1} FYM + vertical mulch of sesame straw at 10m interval @ 5t ha^{-1} increased energy out by 71.2% over control. It also recorded of highest energy use efficiency and energy productivity among all the crop residue management practices with FYM or sole.

Table 7 Energetic of different crop residue management practices in maize cultivation

Treatment	Mean Yield (Kg ha^{-1})		Energy Out-put (MJ ha^{-1})	Energy In-put (MJ ha^{-1})	Energy Use (MJ ha^{-1})	Energy Productivity (gm ms^{-1})
	Grain	Straw				
T_1	2310	5302	129393	7406	17.47	312.0
T_2	1837	4622	110200	7404	14.88	248.1
T_3	1716	4359	104349	7400	14.10	238.7
T_4	1881	4506	108759	7407	14.70	255.0
T_5	1974	4470	109478	7417	14.17	266.1
T_6	2090	4510	111903	7417	15.10	281.8
T_7	2306	5570	134158	7422	18.10	310.7
T_8	2745	6168	151376	7422	20.40	369.8
T_9	1330	3827	88437	7318	12.10	181.7

Conclusion

Thus, it may be concluded that incorporation of crop residues in soil improved the hydro-physical environment and fertility status of the soil, which led to the enhancement of seed yield of maize. Thus, Farm yard manure 5t ha^{-1} + vertical mulch of sesame at 10 m interval @ 5t ha^{-1} can be a good substitution for farmyard manure @ 10t ha^{-1} to physio-chemical properties of soil vis a vis increasing seed yield of maize, water use efficiency, benefit cost ratio and energetic. Similarly, 5t ha^{-1} FYM + vertical mulch of mustard at 10 m interval @ 5t ha^{-1} is second option over 10 t ha^{-1} FYM.

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