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Moisture conservation practices in maize-black gram cropping system in dryland ecosystem and their impact on environment, energetics and economics

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Abstract
Results of study conducted at Dry land Farming Research Station, (MPUAT, Uadipur) Arjia Bhilwara, India during the *kharif* seasons of 2007 and 2008, to assess the impact of *in situ* moisture conservation systems in rainfed maize based cropping system, indicated that strip cropping of maize-black gram (4:8) was the best treatment in terms of environment, energetic, economics and increased maize equivalent yield by 98.4 per cent over control (maize + black gram intercropping (2:2). The Ridging after first intercultural operation (RAFIO) decreased runoff by 25 to 28 per cent over deep tillage and 44 to 45 per cent over shallow tillage during respective years. Deep tillage decreased runoff by 52 per cent and 51 per cent in paired intercropping and strip cropping, respectively, over shallow tillage. RAFIO increased maize grain equivalent yield by 27 to 41 per cent over deep tillage and by 36.02 to 47.59 per cent over shallow tillage in strip cropping and paired intercropping, respectively. RAFIO increased net return by 39 to 106 per cent over deep tillage and by 67.8 to 156.5 per cent over shallow tillage, respectively. Deep tillage increased the yield by 40.4 and 39.4 per cent under strip cropping and inter cropping systems of maize, accounted maximum share of energy input (43.02 – 76.69%) followed by tillage (4.15 – 32.60%) in different moisture conservation practices. The deep tillage required 6.59 times higher energy input than shallow tillage (281.4 MJ ha^{-1}). The energy input for RAFIO was higher (49.18%) in paired intercropping of maize + black gram (90/30) as compared with strip cropping of maize – black gram (4:8).

Keywords: Cropping systems, environment, energetics, runoff, soil loss, economics

1. Introduction
Maize contributes 7 to10 per cent to the food basket of India and 80 per cent of maize producing regions in country belong to rainfed sub- tropical climate with rainfall from 500 to 900 mm**.** The maize productivity in India is only 2114 kg ha^{-1} which is much lesser than the potential and even at this lower level of productivity there is stagnation or intermittent trends of decline. Increasing soil loss and reduction of soil organic matter, unpredictable rainfall, variable and low soil moisture holding capacity and declining water use efficiency are leading reasons for low productivity of maize in these regions (Anonymous 2003) [1], emphasizing the urgent need of identifying efficient soil and moisture conservation practices for enhancing the productivity of maize (Dogra *et al*., 2002) [3]. It has also been recorded that the response of soil and moisture conservation practice varies as per fluctuating amount of monsoon rainfall with coefficient of variation of 33 per cent (Jat *et al*., 2005) [4].
Jat *et al*., (2005 and 2008) [4, 5] observed that soil and moisture conservation practices vary with the fluctuation of quantum of monsoon rainfall with coefficient of variation of 33 per cent. The mean date of effective onset of monsoon is 27th Standard Meteorological Week (SMW) with coefficient of variation 5.4 per cent and withdrawal is 40th SMW with coefficient of variation of 13 per cent with rainy season duration of 12.7 weeks (coefficient of variation 40%) at this location. It also determines the total profitability and energy use efficiency of maize production, input energy used and soil loss. Requirement of energy in maize production vary with the crop establishment methods namely by hand, with assistance of animals, and with tractor mounted

implements. This region is characterized with high variability in rainfall received in terms of quantum and distribution causing detrimental effect on maize acreage, production and productivity. Therefore, befitting *in-situ* soil and moisture conservation system is needed in maize- black gram cropping system. Further, the *in situ* moisture conservation practices require extra cost for inputs. The importance of energy in cropping systems has been adequately emphasized by many workers. The productivity of maize under dryland ecosystems remain very low and unstable due to inadequate and erratic rainfall in such regions, which results into partial or complete failure of crop. Maize is the principal *kharif* cereal crop of Bhilwara district and it occupies 38 per cent of the total cropped area and contributes 55 per cent in production. The annual mean rainfall of the region is 657.5 mm and almost 90 per cent of it is received during the south west monsoon season (June-September). The soils of the regions are less fertile and with low water holding capacity exhibiting vulnerabilities of variable degree of soil erosion and degradation due to high clay content, higher total soluble salts, dispersion ratio, erosion ratio combined with variable rainfall (Jat *et al* 2005) [4].Thus it is of paramount importance to identify suitable cropping systems with matching soil configuration strategies in order to ensure stable and profitable production of rainfed maize at some optimum level through soil and water conservation technologies. Configuration of land, in form of furrows and ridges, during rainy season and raising of combinations of cereal and legume crops are highly beneficial for reduction of run off and soil loss and enhancing the crop yields. (Patil *et al* 2004 and Jat, *et al* 2008) [9, 5].

The fertilizers use in dry lands is complex not only due to their potential environmental hazards but also increase in cost that is not always responded by matching and adequate returns (Pimentel *et al* 2005 and NRC, 2003) [10]. The annual cost on account of soil erosion manifested in form of public health and environmental hazards is prohibitive (Pinmental *et al* 1995). [11] Taking all these attributes in to consideration this research trial was formulated to investigate stability of various cropping systems of maize -black gram and *in situ* moisture conservation system for rain water management and reducing soil and nutrient loss.

2. Materials and Methods

This field experiment was conducted during the *kharif* seasons of 2007 and 2008 (June to October) at Dryland Farming Research Station, Arjia, Bhilwara. The soil properties of experimental site were sandy clay loam in texture, pH was 8.8, EC 0.25 ds/m and organic carbon content 0.26 per cent. The field capacity and wilting point were 23.9 and 9.2 per cent, respectively. The non-replicated experiment was conducted on runoff plots implementing a gross plot size of 25 m x 7 m with 2 per cent slope. The silting and runoff water collecting tanks with multi-slot dimensions were provided at the extreme end for collecting silt and runoff water. The runoff and soil loss were measured for each rainfall events causing runoff. The treatments comprised of, paired intercropping 90/30 with deep tillage & flat sowing (T_1), strip cropping 4:8 with deep tillage & flat sowing (T_2), paired intercropping (90/30), with deep tillage & ridging after first inter culture operation (RAFIO) sowing (T_3), strip cropping (4:8) with deep tillage & ridging after first inter culture operation (RAFIO) (T_4), paired intercropping (90/30), with shallow tillage& flat sowing (T_5), strip cropping (4:8) with shallow tillage & flat sowing, (T_6), paired intercropping (90/30), with shallow tillage & ridging after first inter culture operation (RAFIO) (T_7), maize and blackgram- strip cropping (4:8) with shallow tillage & ridging after first inter culture operation (RAFIO) (T_8), control with shallow tillage (Intercropping of maize + black gram 2:2). (T_9). Maize variety 'PEHM-2' and 'T-9' of black gram which are recommended for the region under dryland ecosystem were grown in rainy season with the recommended package of practices of the zone. The observations were recorded for runoff, soil loss, rainfall and crop yields. Water productivity was worked out by dividing the maize equivalent yield by rainfall during the crop season minus runoff. Economics was evaluated on the basis of prevailing market prices.

The energy input-output were calculated following the methodology as suggested by Mittal *et al.* (1985) [14] and relevant energy equivalents are given in Table 1.

3. Results and Discussion

3.1 Loss of nutrient and improvement of soil health

The magnitude of decline in soil carbon and nutrients are directly influenced by soil losses and such have been shown in Table 2. There was direct relationship between loss of nutrients and soil loss due to runoff. It was evident from data that extent of nutrient loss was the lowest under the strip cropping (90/30).

As the highest proportion of organic carbon remains concentrated in the surface soil that is vulnerable to losses to the maximum extent whenever soil loss is occurred due to runoff. The reduction in loss of carbon was also associated with higher soil water content of the soils in strip cropping of maize-black gram as compared to paired intercropping of these two crops. Similarly, the least loss of nutrients was recorded in strip cropping of maize + black gram (4:8) with deep tillage and RAFIO because of relatively higher water holding of soil. The losses of N, P and K decreased under soil and water conservation practices and under RAFIO the corresponding decline in nutrient loss was to the tune of 63 and 67 per cent under paired intercropping (90/30) and strip cropping of maize – black gram (4:8), respectively. Under deep tillage in comparison to shallow tillage, the nutrient losses decreased up to 72 and 70 per cent under paired intercropping (90/30) and strip cropping of maize – black gram (4:8), respectively. The maximum of nutrient loss (14.09 kg N, 5.6 kg P_2O_5 and 15.6 kg K_2O) was recorded in the paired intercropping of maize – black gram (90/30) with shallow tillage because it caused more amount of runoff leading to soil loss coupled with less moisture content in the soil (Pimental *et al*. 2005 and Pareek *et al*. 2018) [10, 15].

Thus, overall environmental damage was moderated by the strip cropping of maize – black gram (4:8) that was lesser as compared to paired intercropping of maize + black gram due to less loss of soil carbon thereby improving the soil health and ecological integrity, less use of commercial fertilizer (Anonymous, 2003 and Pimental, 2005) [1, 10].

It may precisely be inferred that strip cropping of maize and black gram (4:8) saved greater energy in terms of nutrient loss as compared to inter cropping system of maize + black gram as presented in (Table 2). Results revealed that the strip cropping of maize – black gram (4:8) was recorded with the least loss of energy (107.33 $MJha^{-1}$) with deep tillage and RAFIO. This might be attributed to least soil and nutrients loss. This system reduced the environmental damage as compared to paired intercropping of maize + black gram (90/30) and control. The practice of RAIFO saved energy of nutrient loss by 66 and 65 percent in strip cropping of maize (4:8) and intercropping of maize + black gram (90/30), respectively. Similerly, the deep tillage saved the energy equivalents in term of nutrient loss by

70.6 and 72 per cent in strip cropping of maize + black gram (4:8) and paired inter cropping of maize - black gram (90/30) respectively, over control. This practice also improved the soil health as organic carbon was increased more with strip cropping of maize -black gram (4:8) due to better environment for growing of crops and black gram acts as a barrier for reduction of runoff and soil loss (FAO, 2003).

3.2 Runoff
The strip cropping of maize – black gram (4:8) reduced runoff as compared to paired intercropping maize + black gram (90/30). This might be due to better crop environment and efficient intercultural operation and less competition for soil moisture by decreasing crops area proportions. The maximum reduction of runoff was recorded in the strip cropping of maize – black gram (4:8) with deep tillage and RAFIO over paired intercropping of maize – black gram (2:2). However, the maximum runoff was recorded in paired intercropping of maize + black gram (90/30) with shallow tillage. The paired intercropping of maize – black gram (2:2) decreased runoff in comparison to paired intercropping of maize + black gram (90/30). This might be occurred due to increased plant canopy and plant population or *vice-versa* (Prasad *et al.*, 1984 and Kurothe *et al.*, 2014) [13, 6].

3.3 Yield and Economics
The maize equivalent yield was maximum in strip cropping of maize-black gram (4:8) (Table 1). The highest mean maize grain equivalent (2262 kg ha^{-1}) and B:C ratio (2.71) was also recorded in strip cropping of maize + black gram (4:8) with summer deep tillage and RAFIO which was 98.4 per cent higher than control (11.40 q ha^{-1}). Increased grain yield due to conservation measures was attributed to moisture to crop plants (Pareek *et al.*, 2018) [15]. Similarly, yield water productivity was also maximum under strip cropping treatment with deep tillage.

3.4 Energetics
The total energy input in different *in-situ* moisture conservation practices and maize – black gram cropping system was the highest with paired intercropping of maize – black gram followed by strip cropping of maize – black gram which might be due increased consumption of energy required for seed, sowing, fertilizer, harvesting and threshing operations. The same trend has been observed for harvesting and threshing operation. The highest energy for seed (478 MJ ha^{-1}) was recorded in paired intercropping of maize + black gram (2:2) control due to increased amount of seed for both the crops. The same trend has been observed for fertilizer.
The energy out was higher in strip cropping of maize – black gram (4:8) as compared to paired intercropping of maize - black gram (90/30) and control. The highest energy output (131091.1 MJ ha^{-1}) was recorded in strip cropping of maize – black gram (4:8) with summer deep tillage and ridging after first intercultural operation and the least (65976.6 MJ ha^{-1}) in paired intercropping (30/90) with shallow tillage. Ridging after first intercultural operation gave 33.35 – 36.39 per cent and 22.61 – 28.49 per cent more energy output utilizing only 0.5 – 0.6 per cent and 0.6 – 0.7 per cent higher energy input in paired intercropping of maize + black gram (30/90) and strip cropping of maize – black gram (4:8), respectively. Strip cropping of maize – black gram (4:8) with summer deep tillage with RAFIO recorded maximum energy use efficiency and energy productivity. This might be due to added advantage from by-product yield of the cropping system. The ridging after first intercultural operation increased the energy use efficiency by 32.62 and 35.72 per cent and 27.55 and 21.80 per cent in deep tillage and shallow tillage, respectively. However, the shallow tillage increased the energy use efficiency by 3.48 – 5.64 per cent in strip cropping and paired intercropping maize -black gram (90/30) over deep tillage. The minimum energy use efficiency (10.13) and energy productivity (167.94 K MJ ha^{-1}) was recorded in paired intercropping + maize – black gram (2:2) control. This might be due to the increased plant population for both crops which results into high water requirement and competition for soil moisture thereby product yield of the cropping system is reduced due to the dry spell period and which is common feature of the region (Kumar *et al.*, 2001 and Jat *et al.*, 2005) [8, 4]. It may be concluded that the strip cropping of maize – black gram (4:8) with deep tillage and RAFIO was more energy efficient, productive and economic viable and improves the environment by reducing loss of organic carbon, nutrient (N) and runoff as compared paired intercropping of maize black gram.

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

Table 2: Loss of nutrients and improvement in soil status at end of the study

Treatments	Nutrient loss (kg ha^{-1})			OC%
	N	P	K	
Paired intercropping (90/30) with deep tillage & flat sowing	3.93	1.58	4.32	0.50
Strip cropping (4:8) with deep tillage& flat sowing	3.75	1.49	4.26	0.52
Paired intercropping (90/30) with deep tillage& ridging after sowing	1.91	0.78	2.35	0.54
Strip cropping (4:8) with deep tillage& ridging after sowing	1.53	0.61	1.58	0.60
Paired intercropping (90/30) with shallow tillage& flat sowing	14.09	5.6	15.60	0.27
Strip cropping (4:8) with shallow tillage& flat sowing	12.75	5.18	14.25	0.32
Paired intercropping (90/30) with shallow tillage& ridging after sowing	5.47	2.24	5.96	0.34
Strip cropping (4:8) with shallow tillage& ridging after sowing	4.50	1.86	4.82	0.36
Control (Intercropping maize +black gram 2:2)	6.35	2.60	7.20	0.33

Table 3: Effect of in situ moisture conservation practices on grain, Stover yield and runoff and soil loss in maize- black gram cropping system

Treatments	Maize grain equivalent yield (kg ha^{-1})			Maize stover equivalent yield (kg ha^{-1})			Runoff%	*Soil loss (t ha^{-1})
	2007	2008	Mean	2007	2008	Mean		
Paired intercropping (90/30) with deep tillage & flat sowing	1062	1868	1465	3065	3599	3332	12.40	1.625
Strip cropping (4:8) with deep tillage& flat sowing	1282	2430	1856	3303	4345	3824	11.60	1.58
Paired intercropping (90/30) with deep tillage& ridging after sowing	1552	2579	2066	3637	5114	4376	8.97	0.77
Strip cropping (4:8) with deep tillage& ridging after sowing	1679	2844	2262	3749	5821	4785	8.65	0.60
Paired intercropping (90/30) with shallow tillage& flat sowing	762	1394	1078	2826	2743	2785	26.1	5.925
Strip cropping (4:8) with shallow tillage& flat sowing	913	1691	1302	2933	3335	3134	24.05	5.375
Paired intercropping (90/30) with shallow tillage& ridging after sowing	1329	1858	1594	3189	3626	3408	14.58	2.265
Strip cropping (4:8) with shallow tillage& ridging after sowing	1387	2155	1771	3270	4131	3700	13.58	1.850
Control (maize+ black gram intercropping 2:2)	987	1294	1140	3314	2463	2889	15.15	2.650

*Maize grain –Rs. 790/-, Stover- Rs. 0.60/- per quantal Rainfall during crop growing season (mm) Runoff causing rain fall (cm)

Table 4: Economics of different in situ- moisture conservation practices in maize-black gram intercropping system

Treatments	Maize grain equivalent yield (kg ha^{-1})	Maize Stover eq. yield (kg ha^{-1})	Cost of cultivation (Rs. ha^{-1})	GR (Rs.ha^{-1})	NR (Rs.ha^{-1})	BC Ratio	Water use efficiency (kg ha^{-1} cm)		
							2007	2008	Mean
Paired intercropping (90/30) with deep tillage & flat sowing	1465	3332	8607	13573	4966	1.58	0.47	0.467	0.469
Strip cropping (4:8) with deep tillage& flat sowing	1856	3824	7550	16957	9407	2.25	0.578	0.593	0.586
Paired intercropping (90/30) with deep tillage& ridging after sowing	2066	4376	8707	18947	10240	2.18	0.688	0.618	0.653
Strip cropping (4:8) with deep tillage& ridging after sowing	2262	4785	7650	20741	13091	2.71	0.744	0.661	0.703
Paired intercropping (90/30) with shallow tillage& flat sowing	1078	2785	7407	10187	2780	1.38	0.338	0.357	0.348
Strip cropping (4:8) with shallow tillage& flat sowing	1302	3134	6350	12166	5816	1.92	0.405	0.428	0.417
Paired intercropping (90/30) with shallow tillage& ridging after sowing	1594	3408	7507	14637	7130	1.95	0.589	0.467	0.528
Strip cropping (4:8) with shallow tillage& ridging after sowing	1771	3700	6450	16211	9761	2.51	0.61	0.539	0.575
Control (Intercropping maize +black gram 2:2)	1140	2889	9130	10739	1609	1.18	0.438	0.331	0.385

Table 5: Energy input pattern in maize – black gram intercropping system under different in situ moisture conservation practices

Character treatment	Treatment								
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9
Seed	455.9	263.48	455.9	263.4	455.9	263.4	455.9	263.4	478.0
Fertilizer	3817 (48.12)	2818.8 (43.02)	3817.8 (47.85)	2818.8 (42.82)	3817.8	2818.8 (76.69)	3817.8 (62.23)	2818.8 (68.11)	4545 (66.95)
Machinery	86	86	86	86	86	86	86	86	86
Tillage	2136.6 (26.93)	2136.6 (32.60)	2136.6 (26.78)	2136.6 (32.46)	284.4 (4.63)	281.4 (5.65)	281.4 (4.60)	281.4 (5.62)	281.4 (4.15)
Sowing	240.12 (3.03)	230.8 (3.52)	240.12 (3.01)	230.8	240.12 (3.95)	230.8 (4.64)	240.12 (3.9)	230.8 (4.60)	266.8 (3.93)
Herbicide	90	90	90	90	90	90	90	90	90
Weeding	329	329	329	329	329	329	329	329	329
Ridging after intercultural operation	-	-	45.5 (0.6)	30.5 (0.5)	-	-	45.5 (0.7)	30.5 (0.6)	-
Harvesting	295.4	230.93	295.4	230.93	295.4	230.93	295.4	230.93	308.0
Threshing	470.4	366.52	470.4	366.52	470.4	366.52	470.4	366.52	490.0
Total	7933.42	6552.05	7978.92	6582.55	6078.22	4978.25	6123.72	5008.75	6788.2

Table 6: Energy output, energy use efficiency, energy productivity and energy loss in terms of nutrients loss saving pattern in maize – black gram system

Treatment	Mean maize equivalent yield (kg ha^{-1})		Energy output (MJ ha^{-1})	Energy use efficiency	Energy productivity (gm MJ^{-1})	Energy loss in terms nutrients loss (MJ)
	Grain	Stover				
Paired intercropping (90/30) with deep tillage & flat sowing	1465	3332	81511.5	10.27	184.66	278.16
Strip cropping (4:8) with deep tillage& flat sowing	1856	3824	96115.2	14.67	283.27	266.10
Paired intercropping (90/30) with deep tillage& ridging after sowing	2036	4376	108697.2	13.62	255.17	136.79
Strip cropping (4:8) with deep tillage& ridging after sowing	2362	5435	131091.4	19.91	358.8	107.73
Paired intercropping (90/30) with shallow tillage& flat sowing	1078	2785	65976.6	10.85	177.35	997.77
Strip cropping (4:8) with shallow tillage& flat sowing	1302	3134	75551.4	15.18	261.54	904.77
Paired intercropping (90/30) with shallow tillage& ridging after sowing	1594	3408	84775.8	13.84	260.30	387.48
Strip cropping (4:8) with shallow tillage& ridging after sowing	1771	3700	92633.7	18.49	353.62	318.48
Control (Intercropping maize +black gram 2:2)	1140	2889	68760	10.13	167.94	451.39

4. Conclusion

The Strip cropping of maize –black gram (4:8) with deep tillage and ridging after first intercultural operation is an effective *in situ* moisture conservation practice which gave higher maize equivalent yield and water productivity and net return energy efficient as compared to paired intercropping of maize + black grams (2:2).

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