Vol. 45, No. 2, pp 192-197, 2017
Indian Journal of Soil Conservation
Online URL : http://indianjournals.com/ijor.aspx?target=ijor:ijsc&type=home

Energetics and economic comparisons of *in-situ* moisture conservation practices in maize-blackgram cropping system in dryland ecosystem

M.L. Jat[1], J.K. Balyan and Durga Lal Saini

All India Coordinated Research Project on Dryland Agriculture, Dryland Farming Research Station, Maharana Pratap University of Agriculture and Technology, Arjia, Bhilwara-311001, Rajasthan.

[1]E-mail: mljatbhl@gmail.com

ARTICLE INFO

Article history:
Received : April, 2015
Revised : April, 2017
Accepted : May, 2017

Key words:
B:C ratio,
Cropping systems,
Energetics,
Intercropping,
Runoff,
Soil loss,
Strip cropping

ABSTRACT

A field study was conducted at Dryland Farming Research Station, Arjia, Bhilwara (Rajasthan) during the *kharif* seasons of 2007 and 2008, to assess crop productivity, energetics and economics of *in-situ* moisture conservation practices in maize-blackgram based cropping system under dryland ecosystem. Among the different cropping systems, strip cropping of maize-blackgram (4:8) was most effective in improving energetic and economics of maize equivalent yield by 98.4% over control (maize + blackgram intercropping 2:2 ratio). Ridging after first intercultural operation (RAFIO) reduced the runoff by 25% in 2007 and 28% in 2008 over deep tillage and 44 to 45% over shallow tillage in 2007 and 2008, respectively. The RAFIO decreased the runoff by 25 to 28% over deep tillage and 44 to 45% over shallow tillage during respective years. Similarly, the deep tillage decreased the runoff by 52 and 51% in paired intercropping and strip cropping, respectively over shallow tillage. RAFIO increased mean maize grain equivalent yield by 27 to 41% over deep tillage and by 36 to 48% over shallow tillage in strip cropping and paired intercropping, respectively. Similarly, mean net returns in RAFIO increased by 39 to 106% over deep tillage and by 68 to 157% over shallow tillage, respectively. In deep tillage, yield increased by 40 and 39% under strip cropping and inter cropping system, respectively. In maize, fertilizer accounted higher share of energy input (43.02-76.69%) followed by tillage (4.15-32.60%) under different *in-situ* moisture conservation practices under maize-blackgram cropping system.

1. INTRODUCTION

About 80% of maize is cultivated under rainfed sub-tropical climate in India. In this region, rainfall varies from 500 to 900 mm. Maize alone contributes 7-10% of food basket in India. The mean maize productivity in India is low (2114 kg ha^{-1}) and is lower than most of the maize growing countries in the world. There is an evidence of stagnation or decline in the maize productivity even with the application of recommended rate of N and P (90 kg N ha^{-1}and 50 kg P_2O_5 ha^{-1}). High soil loss and depletion of soil organic matter, erratic rainfall, low soil moisture retention and poor low water use efficiency are major constraints for lower productivity of maize (CRIDA, 2003). It is essential to identify feasible and efficient rainwater conservation practices for enhancing the productivity of maize in the country (Dogra *et al.*, 2002).

Jat *et al.* (2003 and 2008) reported that the response to rainwater conservation practice varies with the total amount of monsoon rainfall (603.2 mm) and its distribution with coefficient of variation of 33% in the southern region of Rajasthan. The mean effective onset of monsoon is 27th standard meteorological week (SMW) with coefficient of variation 5.4% and withdraw is 40th SMW with coefficient of variation of 13% with rainy season duration of 12.7 weeks (coefficient of variation 40%). This also determines the input energy used, soil loss, total profitability and energy use efficiency (EUE) in maize. Energy input used in maize production also varies with the method of crop cultivation namely by hand, animals draft, and with tractor mounted implements used. In this zone, the distribution of rainfall is erratic and uneven which results in low and unstable productivity of maize. A suitable *in-situ* rainwater conservation practice is required in maize-blackgram cropping system. Consequently, the *in-situ* moisture conservation practices require additional input. Maize is the major *kharif* cereal crop cultivated in Bhilwara district and it occupies 38% of the total cropped area and contributes nearly 55% in production. The mean annual rainfall of this region is 657.5 mm and almost 90% is received during the south west monsoon season (June-September). The soils in the region are low in fertility and water retention capacity with moderate to high erosion threats because of high clay content, high total soluble salts, dispersion ratio and erosion ratio coupled with erratic rainfall (Jat *et al.*, 2003). Therefore, suitable cropping system and land treatment techniques in maize cultivation are critically important for stabilizing the maize yield under dryland situations. Opening of ridges and furrows in rainy season and intercropping of cereal and legume has been found effective in reducing runoff and soil loss and increasing the crop yields (Patil *et al.*, 2004, Jat *et al.*, 2008, Jat *et al.*, 2012 and Jat *et al.*, 2013). Similarly Singh *et al.* (2016) reported that ridges and furrows gave higher yield and rainwater use efficiency in pearl millet.

Mostly dryland farmers are not using recommended dose of fertilizers due to environmental hazards and increasing cost of fertilizers. Further, increasing cost of applied fertilizers were not accompanying with corresponding returns (Pimentel *et al.*, 2005 and BANR/NRC, 2003). Thus, estimated annual cost of public and environmental health losses related to soil erosion exceed $45 billion (Pinmental *et al.*, 1995). The change and increase of energy price will increase cost of agricultural inputs, such as land management, fertilizer and fuel, and make future food security major concern (Delgado *et al.*, 2011). Keeping these in view, an investigation was undertaken to study suitability of different *in-situ* moisture conservation practices under maize-blackgram cropping systems for resource conservation, improving productivity and profitability.

2. MATERIALS AND METHODS

A field experiment was conducted during the rainy (*kharif*) seasons of 2007 and 2008 at Dryland Farming Research Station, Arjia, Bhilwara. The soil of the experimental site was sandy clay loam in texture having pH 8.8, electrical conductivity 0.25 dS m^{-1} and organic carbon content 0.26%. The field capacity and wilting point were 23.9 and 9.2%, respectively. The non-replicated experiment was conducted on runoff plots adopting a gross plot size of 25 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, paired intercropping 90/30 cm with deep tillage and flat sowing (T_1), strip cropping 4:8 with deep tillage and flat sowing (T_2), paired intercropping (90/30 cm) with deep tillage and RAFIO sowing (T_3), strip cropping (4:8) with deep tillage and RAFIO (T_4), paired intercropping (90/30 cm) with shallow tillage and flat sowing (T_5), strip cropping (4:8) with shallow tillage and flat sowing (T_6), paired intercropping (90/30 cm) with shallow tillage and RAFIO (T_7), strip cropping (4:8) with shallow tillage and RAFIO (T_8), control with shallow tillage (Intercropping of maize+ blackgram in 2:2) (T_9). Maize variety 'PEHM-2' and 'T-9' of blackgram were the recommended varieties for the region under dryland ecosystem and were cultivated in rainy season with the recommended package of practices for the zone. Runoff, soil loss and crop yields were recorded. Water productivity was worked out by dividing the maize equivalent yield by rainfall during the crop season with runoff deduction. Economics was worked out on the prevailing market prices. The energy input-output were calculated following the methodology as suggested by Mittal *et al.* (1985) and relevant energy equivalents that are furnished in Table 1.

3. RESULTS AND DISCUSSION

Nutrient loss and Soil Health Improvement

The extents of loss of soil carbon and nutrients which are correlated with soil loss and such are presented in Table 2. The losses of nutrients were directly proportional to the soil loss. Results revealed that the lower nutrient loss was recorded in the strip cropping (90/30 cm).

The reduction in inorganic carbon was associated with higher soil water content in the soils in strip cropping of maize-blackgram as compared to paired intercropping of maize + blackgram. Similarly, the lower nutrients loss was recorded in strip cropping of maize + blackgram (4:8) with deep tillage and RAFIO and it was due to lower runoff and higher soil moisture content. The RAFIO decreased the total nutrient loss (N, P and K) by 63 and 67% in paired intercropping (90/30 cm) and strip cropping of maize-blackgram (4:8), respectively.

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

Similarly, deep tillage decreased the nutrient loss by 72 and 70% in paired intercropping (90/30 cm) and in strip cropping of maize-blackgram (4:8), respectively over shallow tillage. The higher 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-blackgram (90/30 cm) with shallow tillage assist produced more amount of runoff leading to soil loss (Fig. 2) (Pimental *et al.,* 2005).

Thus, overall environmental loss was lower by the strip cropping of maize-blackgram (4:8) that was lesser as compared to paired intercropping of maize+blackgram due to lower loss of soil carbon thereby improved the soil health and ecological integrity and lower use of commercial fertilizer (BANR/NRC, 2003 and Pimental, 2005).

Therefore, it is concluded that strip cropping of maize and blackgram (4:8) saved greater energy in terms of nutrient loss as compared to inter cropping system of maize+blackgram as presented in Table 2. Results revealed that the strip cropping of maize-blackgram (4:8) recorded lower energy use (107.33 MJ ha^{-1}) with deep tillage and RAFIO. This might be attributed to lower soil and nutrients loss. The practice RAFIO saved energy in terms of nutrient loss by 66 and 65% in strip cropping of maize (4:8) and intercropping of maize + black gram (90/30 cm), respectively. Similarly, deep tillage saved the energy equivalents in terms of nutrient loss by 70.6 and 72% in strip cropping of maize + blackgram (4:8) and paired inter cropping of maize-blackgram (90/30 cm), respectively over control. The soil health as organic carbon, increased with strip cropping of maize-black gram (4:8). Blackgram acts as a barrier in runoff and soil loss reduction (FAO, 2003).

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

Treatments	Nutrient loss (kg ha^{-1})			OC %
	N	P	K	
T_1	3.93	1.58	4.32	0.50
T_2	3.75	1.49	4.26	0.52
T_3	1.91	0.78	2.35	0.54
T_4	1.53	0.61	1.58	0.60
T_5	14.09	5.6	15.60	0.27
T_6	12.75	5.18	14.25	0.32
T_7	5.47	2.24	5.96	0.34
T_8	4.50	1.86	4.82	0.36
T_9	6.35	2.60	7.20	0.33

Runoff

The runoff reduction in strip cropping of maize-blackgram (4:8) as compared to paired intercropping maize + blackgram (90/30 cm). This might be due to better crop environment and intercultural operations and less competition for soil moisture by decreasing crops area proportions. The higher reduction in runoff was recorded in the strip cropping of maize-blackgram (4:8) with deep tillage and RAFIO over paired intercropping of maize-blackgram (2:2). However, higher runoff was recorded in paired intercropping of maize + blackgram (90/30 cm) with shallow tillage. The paired intercropping of maize-blackgram (2:2) decreased runoff as compared to paired intercropping of maize+blackgram (90/30 cm). This is attributed due to increased plant canopy and plant population (Kale *et al.*, 1994 and Prasad *et al.*, 1984).

Crop Yield and Economics

The maize equivalent yield was higher in strip cropping of maize-blackgram (4:8) (Table 1). The higher mean maize grain equivalent (2262 kg ha^{-1}) and B:C ratio (2.71) was recorded in strip cropping of maize + blackgram (4:8) with summer deep tillage and RAFIO which was 98.4% higher than control (1140 kg ha^{-1}). Increased grain yield due to conservation measures was attributed to the higher soil moisture availability to the crop plants (Singh and Verma, 1995). Similarly, yield and water productivity were also higher under strip cropping with deep tillage.

Table: 3
Effect of *in-situ* moisture conservation practices on grain, stover yield, runoff and soil loss in maize- blackgram cropping system

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

*Maize grain yield: ₹ 790/- q^{-1}, Stover: ₹ 60/- q^{-1}, Rainfall during crop growing season (mm), Runoff causing rainfall (cm)

Table: 4
Economics of different *in-situ* moisture conservation practices in maize-blackgram intercropping system

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

Energetics

The total energy input in different *in-situ* moisture conservation practices and maize-blackgram cropping system was higher with paired intercropping of maize-blackgram followed strip cropping of maize-blackgram which might be due to increased consumption energy required for seed, sowing, fertilizer, harvesting and threshing operations. The higher energy for seed (478 MJ ha^{-1}) was recorded in paired intercropping of maize + blackgram (2:2) due to increased seed rate for both the crops. The same trend has been observed in fertilizer application also.

The energy out was higher in strip cropping of maize-blackgram (4:8) as compared to paired intercropping of maize-blackgram (90/30 cm) and control. The higher energy output (131091.1 MJ ha^{-1}) was recorded in strip cropping of maize-blackgram (4:8) with summer deep tillage and RAFIO and the lower (65976.6 MJ ha^{-1}) in paired intercropping (30/90 cm) with shallow tillage. RAFIO produced 33.35-36.39% and 22.61-28.49% more energy output utilizing only 0.5-0.6 and 0.6-0.7% higher energy input in paired intercropping of maize + blackgram (30/90 cm) and strip cropping of maize-blackgram (4:8), respectively. Strip cropping of maize-blackgram (4:8) with summer deep tillage with RAFIO recorded higher EUE and energy productivity. This might be due to the by-product yield in the cropping system. The RAFIO increased the EUE by 32.62 and 35.72% and 27.55 and 21.80% in deep tillage and shallow tillage, respectively. However, in shallow tillage the EUE increased by 3.48-5.64% in strip cropping and paired intercropping maize-blackgram (90/30 cm) over deep tillage. The lower EUE (10.13) and energy productivity (167.94 K MJ ha^{-1}) was recorded in paired intercropping of maize + blackgram (2:2). This might be due to the increased plant population of both crops and it resulted in higher water requirement and competition for soil moisture, thereby reduced the yield of both the crops and also due to the dry spell period which is common feature in the region (Jat *et al.*, 2003). It may be concluded that the strip cropping of maize-blackgram (4:8) with deep tillage and RAFIO was more energy efficient, productive and economically viable and improved the soil health by reducing organic carbon, nutrient (N) and runoff losses as compared to paired intercropping of maize blackgram.

4. CONCLUSIONS

It is, therefore, be concluded from the present study that the strip cropping of maize-black gram (4:8) with deep tillage and RAFIO is an effective *in-situ* moisture conservation practice that produced higher maize equivalent yield, water productivity and net energy benefit as compared to paired intercropping of maize + black grams (2:2).

Table: 5
Energy input pattern in maize-blackgram intercropping system under different *in-situ* moisture conservation practices

Character	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 interculture 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 term of nutrients loss in maize-blackgram system

Treatment	Mean maize equivalent yield (kg ha^{-1})		Energy output (MJ ha^{-1})	Energy use efficiency	Energy productivity (g MJ^{-1})	Energy loss in terms of nutrients loss (MJ)
	Grain	Stover				
T_1	1465	3332	81511.5	10.27	184.66	278.16
T_2	1856	3824	96115.2	14.67	283.27	266.10
T_3	2036	4376	108697.2	13.62	255.17	136.79
T_4	2362	5435	131091.4	19.91	358.8	107.73
T_5	1078	2785	65976.6	10.85	177.35	997.77
T_6	1302	3134	75551.4	15.18	261.54	904.77
T_7	1594	3408	84775.8	13.84	260.30	387.48
T_8	1771	3700	92633.7	18.49	353.62	318.48
T_9	1140	2889	68760	10.13	167.94	451.39

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