Biological Forum – An International Journal **15(9): 1096-1100(2023)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Productivity Profitability and Resource Use efficiency of Rain Fed Millet based Cropping System

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(Received: 10 July 2023; Revised: 16 August 2023; Accepted: 06 September 2023; Published: 15 September 2023)
(Published by Research Trend)

ABSTRACT: A field experiment was conducted in the Regional Research Transfer & Technology Station at Semiliguda under rainfed condition during 2019 & 2020. The soil of the experimental site was sandy clay loam with pH 5.06, organic carbon 5.03 g/kg, available N 372 kg/ha, P 33.2 kg/ha and K 313.0 kg/ha. The experiment was laid out in a randomized complete block design with twelve treatments and four replications. The treatments were, finger millet(sole), little millet(sole), redgram (sole), blackgram (sole), finger millet - horsegram, little millet- horsegram, finger millet + redgram (4:2), little millet + redgram(4:2), finger millet + black gram(4:3), little millet + black gram(4:3), finger millet + black gram (4:3) -horsegram, little millet + black gram(4:3)-horsegram. The finger millet equivalent yield was higher in 2020 (2186kg/ ha) compared to 2019 (2125 kg/ha). However the average yield of both the years were found to be (2155 kg/ha). Under sole cropping system FMEY was maximum in redgram (1836 kg/ha) followed by little millet (1773kg/ha), finger millet (1641kg/ha) and black gram (1589 kg/ha). Under intercropping systems the maximum FMEY was observed under Finger millet + redgram (2358 kg/ha) followed by little millet + black gram (4:3) (1982 kg/ha) and finger millet + black gram (4:3) (1878 kg/ha) which were at par but significantly higher than that under little millet + red gram (4:2)(1803 kg/ha). But when horse gram was added in sequence, maximum FMEY of (3153 kg/ha) was observed under little millet + black gram(4:3) – horse gram system which was at par with Little millet –horse gram system (2842 kg/ha) but significantly higher than that of finger millet + Black gram(4:3) –horse gram (2602 kg/ha) and Finger millet-horsegram (2326 kg/ha). However the highest FMEY was recorded under little millet + blackgram (4:3)-horsegram system (3153 kg/ha) followed by little millet – horsegram system (2842kg /ha), which is at par, but significantly higher than all other Rs 54,906/ha) returns, production efficiency (Rs 361/ha/day), , maximum area time equivalent ratio(ATER) 1.28, maximum advantage index 22119 and highest net return per rupee invested (Rs 2.18).

Keywords: Intercropping, net returns, production efficiency, equivalent ratio.

INTRODUCTION

India is a global leader in the production of millet. Owing to their greater flexibility and physiological efficiency, millets are a promising crop for the southern half of Odisha, which includes ten districts and an area of about 6.6 million hectares. Subsistence farming provides the tribal inhabitants of this area with a means of subsistence. Most arable land is found in rainfed uplands known as "dangar lands," which are located between hillocks and bottom valleys. The predominant crop during the rainy season on these plains is finger millet, sometimes referred to as mandia locally. It makes up over 20% of the entire cultivated land and is used in the area as a variety of food items. 58610ha of the Koraput district's total agricultural land is used for finger millet farming, with 53.11MTs of finger millet produced there and a yield of 906 kg/ha. The district's entire cultivated area is made up of 12110ha of little millet, with productivity and production levels of 512 kg/ha and 6.20 MTs, respectively. Finger millet and tiny millet occupy 58360ha and 12110ha, respectively, when only the kharif season is taken into account. (District agriculture strategy committee meeting report, 2020–21). High rainfall (1,500 mm/year), rolling topography, high erodibility of dangar lands, inappropriate crop selection, up-down cultivation, monoculture, cultivated fallows, and occurrence of drought during critical crop growth stages all contribute to the high vulnerability of dangar lands to water erosion (Chaudhary *et al.,* 1999). These factors significantly reduce crop productivity. Pigeonpea is a tall growing, wide-spaced crop with a deep root-system which can accommodate short-duration cereals and pulses having a shallow root-system and utilize the benefit of initial slow growth of pigeonpea (Das *et al*., 2016).Cultivation of fast growing crops like blackgram, cowpea as intercrop can potentially boost the farm

productivity and economic sustainability (Yadav *et al*., 2021).

In dryland environments, intercropping has long been acknowledged as a type of biological insurance against hazards and abnormal rainfall behaviour (Dutta and Bandyopadhyay 2006). This allows for increased crop diversity. According to Kumar and Singh (2006), it improves cropping intensity, productivity, profitability, and the best use of soil, water, nutrients, and sunlight. In addition to boosting overall output and revenue, intercropping millets with legumes improves soil physical characteristics, increases soil fertility, and reduces runoff, all of which contribute to moisture conservation. Legumes like blackgram and pigeonpea, being hardy, may constitute potential intercrops in finger millet under rainfed conditions. Intercropping may be an alternate practice for surmounting low productivity in case of low input low output and small-scale farming systems (Dadabhau, 2014). The intercropping of millets with legumes can enhance the economic returns per unit area. Intercropping is considered the most suitable for sustaining crop productivity (Buttar *et al.,* 2023)

MATERIALS AND METHOD

A field experiment was conducted in the Regional Research Transfer & Technology Station at Semiliguda under rainfed condition during 2019 & 2020. The soil of the experimental site was sandy clay loam with pH 5.06, medium in organic carbon 5.03 g/kg, medium in available N 372 kg/ha, medium in P 33.2 kg/ha, high in K 313.0 kg/ha and S 10.5 ppm. The experiment was laid out in a randomized complete block design with twelve treatments and four replications. The treatments were, finger millet(sole), little millet(sole), redgram (sole), blackgram (sole), finger millet - horsegram, little millet- horsegram, finger millet + redgram (4:2), little millet + redgram(4:2), finger millet + black gram(4:3), little millet + black gram(4:3), finger millet + black gram (4:3) -horsegram, little millet + black gram(4:3)-horsegram.

Geographically, this experimental site falls under Eastern Ghat High Land zone of Odisha. Having red laterite soil and is located at18°42' N latitude and 82° 30' E longitudes and at an elevation of 884.0 meters above mean sea level. Finger millet as the main crop and black gram and red gram as inter crops were sown during rainy season. Finger millet and little millet were sown with a spacing of 20cm × 10cm and seed rate of 10 kg ha^{-1}. Red gram with spacing of 60cm × 30 cm and seed rate of 15 kg ha^{-1} for sole crop and as inter crop with the seed rate @ 11 kg ha^{-1}, black gram was sown with spacing of 30 cm x 10cm and seed rate of 15 kg ha^{-1} for sole crop and as inter crop seed rate @ 8.4 kg ha^{-1}. Millet plant population was 50%. In case of inter crop red gram plant population was 75% and black gram population was 56% per cent of normal sole cropping. During post rainy season, horse gram was sown as sole crop with a row spacing of 30 cm and the intra-row spacing of 10 cm was maintained by thinning operation 20 days after sowing. The crop was sown after cultivating the plots with a seed rate of 15 kg ha^{-1}. Line sowing was done using trench hoe and seeds were covered with soil after sowing. FYM @ 5 t ha^{-1} was applied at the time of last ploughing as per the treatment. In case of finger millet, little millet, red gram, black gram fertilizer applied @ 40:15:15, 20:7.5:7.5, 20:30:30 & 20:30:30($N:P_2O_5:K_2O$) kg ha^{-1} respectively. Full dose of P, K & 50% N were applied as basal and rest 50% N were applied to the crop at first & second earthing up, respectively.

The intercropping systems were evaluated in terms of finger millet equivalent yield (q/ha), system productivity (kg/ha/day) and economic returns. Economic returns (Rs/ha) for individual crop in intercropping system were calculated on the basis of prevailing market rates of inputs and selling of produce. The system productivity was calculated by converting the yield of all crops grown in intercropping system in terms of finger millet equivalent yield in kg/ha and dividing it with the duration of intercropping system. It was expressed as kg/ha/day. Yield of individual crop was converted into equivalent yield (q/ha) on the basis of prevailing market price of the crop. It was calculated by the following formula:

$$\text{FMEY (kg ha}^{-1}) = \frac{\text{Yield of inter crop (kg ha}^{-1}) \times \text{Price of inter crop (kg ha}^{-1})}{\text{Price of finger millet (Rs kg}^{-1})}$$

The price (Rs./q) of Finger millet – 3150/- ; Little millet – 4600/-; Redgram – 5700/-; Blackgram – 5700/-; Horse gram – 5800/- for the year (2019-20) and Price (Rs./q) : Finger millet – 3300/-; Little millet – 4700/-; Redgram – 6000/-;Blackgram – 6000/-;Horse gram – 6000/- for the year (2020-21).

RESULTS AND DISCUSSION

Grain yield of a crop or cropping system is the final indicator for evaluating the superiority of the treatment. Inclusion of legumes like black gram as intercrop or horsegram as sequence crop with LM and FM has additive effect over the yield of base crop as well as succeeding crop (Table 1). It enhanced the productivity and profitability of the system.

Considering the total system, highest FMEY (3144kg/ha) was recorded under LM + BG - HG system (T_{12}) which was on par with that of LM - HG system (T_6, 2854 kg/ha) but significantly higher than all other systems i.e. FM + BG – HG system (T_{11}) followed by FM – HG (T_5), FM + RG (T_7) with FMEY of 2485 kg/ha , 2326 kg/ha and 2226 kg/ha respectively. However, sole BG recorded the lowest FMEY (1441 kg/ha). Highest FMEY (3144kg/ha) was recorded under LM + BG - HG (T_{12}), which was 26.5%, 35.1%, 41.2 % and 118% higher than that of FM + BG – HG (T_{11}), FM – HG (T_5), FM + RG (T_7) and sole BG (T_4), respectively. This has been resulted due to an efficient use of nutrients, moisture, light and space as reported by Anchal Dass and Sudhishri (2010). Also, this might be due to higher grain yield coupled with

higher market price of component crops (Kumar *et al*., 2022).

Maitra *et al*. (2001) who reported that FM produced more yield under intercropping with RG as compared to sole cropping due to higher LAI, dry matter and yield attributes of the system. In *kharif* considering all the cropping systems, maximum total grain yield (FMEY, 2226 kg/ha) was recorded in finger millet + red gram (T_7) system, which was 24.4%, 24.5%, 25.6%, 33.6%, 35.7% and 54.4% higher than sole LM (T_2), LM + RG (T_8), FM + BG – HG (T_{11}), FM + BG (T_9), sole RG (T_3), sole FM (T_1) and sole BG (T_4), respectively. Higher yield achieved in FM+ RG compared to other inter cropping and sole cropping system was mainly due to compatibility of intercropping and best use of space between rows, better availability of light, nutrients received from different layer of soil because of tap root system of red gram and fibrous root in finger millet, efficient use of resources and favorable inter and intra species competition. Intercropping increased the fertility status of soil by leaf fall of legume crops which increased the organic matter and organic carbon of soil and finally improved the physical, chemical and biological environment of the soil favouring increased availability of most of the required macro and micro nutrient to the crop. Moreover, intercropping stimulated the plants in a complementary way which helped in higher LAI, dry matter accumulation and energy obtained from photosynthesis and carbohydrate metabolism that is stored in ATP and ADP for growth and production. Thus it enhances higher value of all plant characters, yield attributes and finally seed yield, which had a possible effect on grain yield. The results were evidenced with studies of Ramamoorthy *et al*. (2002); Mahto *et al*. (2007); Anchal Das *et al.* (2010); Kachroo *et al.* (2014); Shwethanjali *et al.* (2018).

Table 1: Finger millet equivalent yield of component crops in millet based cropping system.

Treatments	FMEY(kg/ha)														
	Kharif									Rabi			Total		
	Main crop			Inter crop			Total			Sequence crop			System		
	2019	2020	Mean	2019	2020	Mean	2019	2020	Mean	2019	2020	Mean	2019	2020	Mean
T1. FM (Sole)	1606	1674	1640	-	-	-	1606	1674	1640	-	-	-	1606	1674	1640
T2. LM (Sole)	1758	1868	1813	-	-	-	1758	1868	1813	-	-	-	1758	1869	1813
T3. RG (sole)	1620	1711	1666	-	-	-	1620	1711	1666	-	-	-	1620	1711	1666
T4. BG (Sole)	1431	1452	1441	-	-	-	1431	1452	1441	-	-	-	1431	1452	1441
T5. FM - HG	1610	1659	1635	-	-	-	1610	1659	1635	679	705	692	2289	2364	2326
T6. LM – HG	1723	1938	1831	-	-	-	1723	1938	1831	1017	1031	1024	2740	2969	2854
T7. FM + RG(4:2)	928	956	942	1259	1309	1284	2187	2265	2226	-	-	-	2187	2265	2226
T8. LM + RG(4:2)	1078	1078	1078	695	727	711	1773	1805	1789	-	-	-	1773	1805	1789
T9. FM + BG(4:3)	870	894	882	858	920	889	1728	1814	1771	-	-	-	1728	1814	1771
T10. LM + BG(4:3)	1081	1087	1084	874	933	904	1955	2020	1988	-	-	-	1955	2020	1987
T11. FM + BG (4:3)- HG	865	890	878	890	928	909	1755	1818	1787	681	716	699	2437	2534	2485
T12. LM + BG(4:3)- HG	1118	1133	1126	931	967	949	2049	2100	2075	1064	1076	1070	3113	3176	3144
SEm(+)	-	-	-	-	-	-	151	159	155	-	-	-	198	215	205
CD (P=0.05)	-	-	-	-	-	-	444	467	456	-	-	-	580	630	601

Among all the systems, highest production cost (Rs.46,963/ha) was estimated in finger millet + black gram – horse gram system (T_{11}) which was on par with that in T_{12}, the little millet + black gram - horse gram system.

(Rs.46,526/ha), in T_5, the finger millet - horse gram system (Rs.45,909/ha) and inT_6, the little millet - horse gram system (Rs.45,086/ha) but significantly higher than all other systems, followed by Rs.42,706/ha in finger millet + red gram (T_7), Rs.42,269/ha in little millet + red gram (T_8) and Rs 35,547/ha in the sole crop of red gram (T_5), Lowest production cost of Rs.31,182/ha was estimated in sole crop of little millet (T_2).

LM + BG - HG system (T_{12}) recorded highest gross return, net return, B:C ratio of Rs.1,04,819/ha, Rs. 14,639/ha and 2.18, respectively. This might be due to significant increase in yield under this treatment. Sole black gram recorded lowest gross return, net return and B:C ratio (Rs.52,916/ha, Rs. 54,906/ha and 1.46, respectively). Intercropping in farming systems alleviates the net produce of different crops and these diverse systems provide a higher cash return to small holding farmers than monocropping**.**

Table 2: Economics of millet based cropping systems.

Treatments	Gross Cost (Rs/ha)			Gross Return (Rs/ha)			Net Return (Rs/ha)			B:C		
	2019	2020	Mean	2019	2020	Mean	2019	2020	Mean	2019	2020	Mean
T1. FM	31990	32120	32055	50589	55242	52916	18599	23122	20861	1.58	1.72	1.65
T2. LM	31082	31282	31182	55384	61664	58524	24302	30382	27342	1.78	1.97	1.88
T3. RG	35447	35647	35547	51026	56473	53750	15579	20826	18203	1.44	1.58	1.51
T4. BG	31807	31907	31857	45076	47916	46496	13269	16009	14639	1.42	1.50	1.46
T5. FM - HG	45844	45974	45909	72117	77997	75057	26273	32023	29148	1.57	1.70	1.63
T6. LM – HG	44936	45236	45086	86296	97978	92137	41360	52742	47051	1.92	2.17	2.04
T7. FM + RG(4:2)	42580	42831	42706	68891	74748	71819	26311	31917	29114	1.62	1.75	1.68
T8. LM + RG(4:2)	42126	42412	42269	64715	69398	67057	22589	26986	24788	1.54	1.64	1.59
T9. FM + BG(4:3)	33807	32364	33086	54423	59869	57146	20616	27504	24060	1.61	1.85	1.73
T10. LM + BG(4:3)	33353	31945	32649	61571	66658	64115	28218	34713	31466	1.85	2.09	1.96
T11. FM + BG (4:3)- HG	47661	46264	46963	76758	83610	80184	29097	37346	33221	1.61	1.81	1.71
T12. LM + BG(4:3)- HG	47207	45845	46526	98044	104819	101432	50837	58974	54906	2.08	2.29	2.18
SEm(±)	706	700	703	1184	1292	1238	478	592	535	0.030	0.033	0.031
CD (P=0.05)	2075	2057	2066	3480	3797	3639	1406	1741	1573	0.087	0.096	0.091

Area time equivalent ratio (ATER) and Monetary advantage index (MAI). Aasim *et al.* (2008), noticed area time equivalent ratio (ATER) provides more realistic comparison of the yield advantage of intercropping over sole cropping in terms of variation in time taken by the component crops of different intercropping systems. The ATER values were lesser than LER values indicating over estimation of resource utilization. ATER is free from problems of over estimation of resource utilization contrary to LER (Nedunchezhiyan, 2011). It indicated not only the efficient use of land but also efficient use of time. Total ATER value was more than one in all intercropping system except LM + RG system (T_8) due to low yield of system for lodging effect of little millet on RG crop.

Highest ATER was recorded in LM + BG – HG (T_{12}, 1.28) which was 4.9%, 17.4%, 19.6%, 20.7% and 80.2% higher than LM + BG (T_{10}, 1.22), FM + RG (T_7, 1.09), FM + BG – HG (T_{11}, 1.07), FM+ BG (T_9,1.06) and LM+RG (T_8, 0.71), respectively. This is due to complementary relation of LM and BG intercropping system, when horse gram taken in sequence, resulting in higher yield of the component crops in the system.

Nedunchezhiyan (2011) noticed monetary advantage index (MAI) values were positive which showed a definite yield advantage. LM + BG - HG (T_{12}) recorded highest monetary advantage index 22119 which was 20%, 87%, 93% and 188% higher than FM + RG system (T_7, 18426), LM+BG (T_{10}, 11767), FM + BG – HG (T_{11}, 11402) and FM + BG (T_9, 7666), respectively. Lowest MAI was recorded in little millet + red gram (T_8, 1363). These results imply that it was more economically viable to take sequence crop horse gram after little millet and black gram inter cropping in rainfed farming system. Both the *kharif* crops were harvested at 80 days after sowing. So sequence crop horse gram was sown earlier in 1st week of September, resulted in more yield of horsegram with adequate use of residual moisture in soil. This is in proximity with the findings of Sahu *et al.* (2001).

Table 3: Area time equivalent ratio (ATER) and Monetary advantage index(MAI) of millet based cropping system.

Treatments	ATER			MAI		
	2019	2020	Mean	2019	2020	Mean
T1. FM	-	-	-	-	-	-
T2. LM	-	-	-	-	-	-
T3. RG	-	-	-	-	-	-
T4. BG	-	-	-	-	-	-
T5. FM - HG	-	-	-	-	-	-
T6. LM – HG	-	-	-	-	-	-
T7. FM + RG(4:2)	1.10	1.08	1.09	18051	18801	18426
T8. LM + RG(4:2)	0.72	0.70	0.71	2623	102	1363
T9. FM + BG(4:3)	1.05	1.07	1.06	6730	8602	7666
T10. LM + BG(4:3)	1.23	1.22	1.22	11325	12208	11767
T11. FM + BG (4:3)- HG	1.06	1.07	1.07	10638	12166	11402
T12. LM + BG(4:3)- HG	1.29	1.27	1.28	21801	22436	22119
SEm(±)	0.089	0.089	0.089	3166	3507	3322
CD (P=0.05)	0.22	0.22	0.22	7870	8718	8259

CONCLUSIONS

Thus, the study concluded that due to complementary relation of LM and BG intercropping system, when horse gram taken in sequence, resulting in higher yield of the component crops in the system. Inclusion of legumes like black gram as intercrop or horse gram as sequence crop with LM and FM has additive effect over the yield of base crop as well as succeeding crop. LM + BG - HG system (T_{12}) recorded highest FMEY (3144kg/ha), highest gross return, net return, B:C ratio of Rs.1,04,819/ha, Rs. 14,639/ha and 2.18, respectively. This has been resulted due to an efficient use of

nutrients, moisture, light and space. Also may be due to higher grain yield coupled with higher market price of component crops. Among all the systems minimum production cost Rs.31,182/ha was estimated in LM (T_2) followed by BG (Rs.31,857/ha in T_4) and FM (Rs.32,055/ha in T1) which were on par but significantly lower than rest other systems, where as maximum production cost Rs.46,963/- was noticed in FM+BG-HG system (T_{11}), which was on par with that of LM+BG-HG (Rs.46,526/- in T_{12}), FM-HG (Rs.45,909/- in T_5) and LM - HG (Rs.45,086/- in T_6) and significantly higher over rest of the treatments. Highest ATER was recorded in LM + BG – HG (T_{12}, 1.28). LM + BG - HG (T_{12}) recorded highest monetary advantage index 22119. These results imply that it was more economically viable to take sequence crop horse gram after little millet and black gram inter cropping in rainfed farming system.

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How to cite this article: Sunita Dandasena, Sabyasachi Biswal, Monika Ray and Ansuman Nayak (2023). Productivity Profitability and Resource Use efficiency of Rain Fed Millet based Cropping System. *Biological Forum – An International Journal, 15*(9): 1096-1100.