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Production potential and soil health of diversified production system of hill and plateau region of eastern India

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ABSTRACT

A field experiment was conducted at the Farming System Research Centre for Hill and Plateau Region, Ranchi, Jharkhand during 2016–19 on acidic soil to evaluate the production potential, competitive indices and economics of ten diversified cropping systems. Results revealed that rice equivalent yield of intercropping with finger millet+horse gram (7.4 t/ha) was recorded significantly higher compared to finger millet+black gram (6.7 t/ha), rice+black gram (5.55 t/ha), rice+horse gram (5.83 t/ha) and sole rice cropping (1.54 t/ha). Higher gross return (₹285441/ha), net return (₹217159/ha), B:C ratio (4.18), economic efficiency (₹595/ha/day), crop productivity (20.3 kg/ha/day) were recorded with finger millet+horse gram, which was significantly higher as compared to finger millet+black gram, rice+black gram, rice+ horse gram and sole rice cropping. Significantly higher land equivalent ratio (2.42) was noted with rice+black gram over rice+horse gram, finger millet+blackgram and finger millet+horse gram. Higher positive aggresivity index (0.22) was recorded with rice+blackgram. Diversified production systems with finger millet+ horse gram had more monetary advantage index (₹153100/ha) over finger millet+black gram, rice+black gram and rice+horsegram. Thus, finger millet+horsegram was noted the most productive, resource-use efficient and remunerative cropping system under rainfed production system of hill and plateau region of eastern India.

Keywords: Aggresivity index, ATER, Economics, LER, REY, SYI

Crop diversification, practice of cultivating more than one variety of crops belonging to same/different species in a given area in form of rotation or intercropping, appears as a potential solution to maintaining the crop productivity, soil fertility, environmental sustainability and reducing pest/ disease incidents (Pan *et al.* 2020). Diversified cropping system tends to be more resilient and agronomically stable due to reduced insect and weed pressure, erosion due to use of cover crop and reduced use of fertilizers in mixed cropping, which includes leguminous crops that add nitrogen in soil and help in increasing the soil fertility. Diversification of crops/cultivars can be an effective strategy for achieving the objectives of food and nutrition security, judicious use of land and water resources, sustainable agricultural development, employment generation, source of income growth and poverty alleviation (Kumar *et al.* 2020).

Rice (*Oryza sativa* L.) stands first among all the foodgrain crops of world and a staple food of more than half of world's population (Kumar *et al*.2021a). It contributes~40% of total food grain production in India (Kumar *et al*. 2021b). Rice occupies ~37 mha area with productivity of 1-1.1 t/ha, which is not comparable to developed countries (Kumar *et al.* 2019a). Intercropping being a unique property of tropical and sub-tropical areas is becoming popular among small farmers, as it offers possibility of yield advantage relative to sole cropping through yield stability and improved crop yields (Kumar *et al.* 2019b). It helps in maintaining the soil health, making efficient use of nutrients and ensuring the economic utilization of land, labour and capital (Kumar *et al.*2019c). Rice-based cropping system is a major production system, which involves rotation of crops including cereals, pulses, oilseeds and vegetables. Intercropping rice with other crops like black gram, green gram, maize and finger millet is a

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common practice under rainfed conditions in north-eastern parts of the country. Thus, the present study was carried out to determine the most productive, resource-efficient and alternative sustainable diversified production system for hill and plateau region of eastern India.

MATERIALS AND METHODS

Experiment was conducted at the research farm of ICAR-Research Complex for Eastern Region, Farming System Research Centre for Hill and Plateau Region, Ranchi, Jharkhand (23. 35ºN and 85.33ºE at 629 m altitude) during *kharif* 2016–19. Soil of the experimental site was sandy loam (sand: 68.6%, silt: 20.3%, clay:11.1%) and acidic with *p*H (5.17). It was low in fertility, status being low in organic carbon (0.43%) and low in available N (195.5kg/ha), and medium in available P (35.7kg/ha) and K (241.2 kg/ha). In sole and diversified production system, rice, finger millet, black gram, horse gram, vegetable cowpea and pigeonpea were sown at row spacing, plant-to-plant distance and fertilizer application doses presented in Table 1. Rice and finger millet with black gram, horse gram were sown in 1:1 diversified production system. Experiment was laid out in a randomized block design with three replications comprising ten treatment combinations. Non-rice crop was used to estimate rice equivalent yield (REY), competitive indices and monetary advantage. Weather data was recorded on daily basis (Fig 1). Land equivalent ratio (LER) indicates efficiency of intercropping in using resources of environment compared with sole cropping. LER indicates total land area required by sole crops to achieve the same yield as intercrops (Willey 1985). Area time land equivalent ratio (ATER) takes into account duration of crops and permits an evaluation of crops on yield per day basis.Aggressivity index is often used to indicate how much relative yield increase in crop 'a' is greater than that for crop 'b' and *vice versa* in an intercropping system (McGilchrist 1965). Sustainable yield index (SYI) was calculated as per Guggari and Kalaghatagi (2004).

Data were subjected to analysis of variance using SPSS program version 8. The treatment mean differences were separated and tested by Fisher's protected least significant difference (LSD) at a significance level of P=0.05.

Table 1 Common agronomic practices followed in rainfed agro-ecosystem of hill and plateau region of eastern India

Crop	Variety	Spacing (cm)	Fertilizers (kg/ha)		
			N	P	K
Rice	BVD-109	30×10	40	20	20
Finger millet	BBM-10	30×10	40	30	20
Black gram	Uttara	30×20	25	50	25
Horse gram	Birsa Kulthi-1	30×20	20	40	20
Vegetable Cowpea	Swarna Mukut	60×25	20	40	20
Pigeon pea	UPAS-120	75×25	25	50	25

RESULTS AND DISCUSSION

Effect on productivity: Mean data of four consecutive years revealed that grain yield of vegetable cowpea production system recorded the highest grain yield (10 t/ha) and it was minimum in sole rice (1.54 t/ha) (Table 2). In diversified system, maximum grain yield (3.53+2.51 t/ha) was recorded with finger millet+horse gram system and lower with rice+black gram (2.01+2.03t/ha). Vegetable cowpea production system had the highest rice equivalent yield (15.4 t/ha) than all other production systems. Minimum REY (1.54 t/ha) was found in sole rice cropping. Finger millet+horse gram recorded maximum REY (7.4 t/ha) and it was significantly higher than rest of the production system. Similar findings are also reported by Nagoli *et al*. (2017).

Highest crop productivity was noted in vegetable cowpea production system (42.1 kg/ha/day) (Table 2).Vegetable cowpea-based system was noted significantly superior to other production systems. Vegetable cowpea can be adjusted in rice-wheat system for increasing income per unit area and improving soil health (Kumar *et al.* 2021b). Being, a short duration crop (65-70 day), it can be grown easily during fallow periods of wheat and rice. Kumar *et al*. (2019c) also reported higher productivity and profitability with inclusion of vegetables/pulses in rice-based system. Kumar *et al*. (2021a) reported that maximum production efficiency (118 kg/ha/day) was noted in rice-vegetable production system. Maximum SYI was obtained in rice-brinjal sequence and minimum in sole rice (0.18) (Prasad *et al*. 2013). Maximum carbon output (8.9 t CE/ha) was recorded with finger millet+horsegram. Highest carbohydrate equivalent yield (5.46 t/ha) was recorded in vegetable cowpea system. Similar results were also reported by Nagoli *et al*. (2017).

On economics: Finger millet+horse gram system gave significantly higher gross returns and net returns (₹285441 and ₹217159/ha) (Table 2). Vegetable

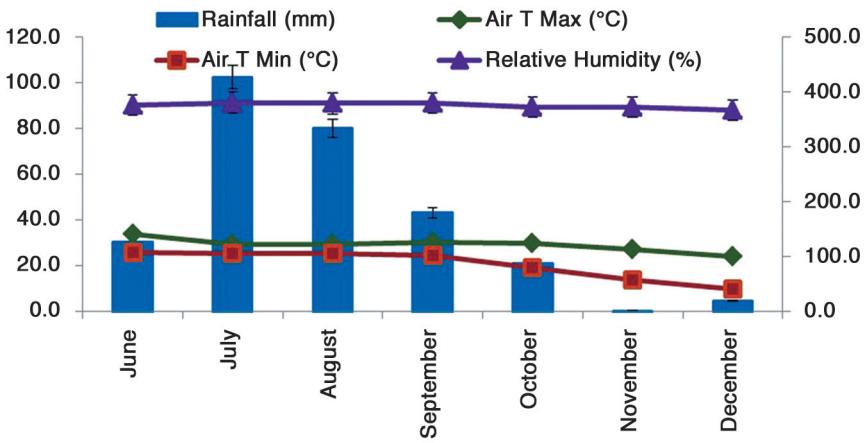

Fig 1 Weather attributes during the experimentation (Mean of 4-years).

Table 2 Rice equivalent yield (REY) and economics of diversified production system in rainfed agro-ecosystem of eastern hill and plateau hill region

Treatment	Grain yield (t/ha)	REY (t/ha)	Crop productivity (kg/ha/day)	Gross returns (₹/ha)	Net returns (₹/ha)	B: C ratio	Economic efficiency (₹/ha/day)	Relative economic efficiency
Rice sole	1.54	1.54	4.2	45747	14392	1.46	39.4	-
Finger millet sole	3.55	5.96	16.3	139980	107525	4.31	294.6	647.1
Blackgram sole	1.82	8.37	22.9	112648	76179	3.09	208.7	429.3
Horse gram sole	2.16	8.07	22.1	116908	81081	3.26	222.1	463.4
Vegetable cowpea sole	10.01	15.35	42.1	209271	172634	5.71	473.0	1099.5
Pigeon pea sole	3.05	12.05	33.0	228323	182159	4.95	499.1	1165.7
Rice + Blackgram (1:1)	2.01+2.03	5.55	15.2	179280	111456	2.64	305.4	674.4
Rice + Horse gram (1:1)	1.39+2.67	5.83	16.0	183363	116181	2.73	318.3	707.3
Finger millet + Blackgram (1:1)	3.37+1.88	6.67	18.3	252758	183834	3.67	503.7	1177.3
Finger millet + Horse gram (1:1)	3.53+2.51	7.40	20.3	285441	217159	4.18	595.0	1408.9
LSD (P=0.05)	-	0.72	1.97	14847	10884	0.302	29.82	-

Mean data of 4 years

cowpea production system as recorded the maximum B:C ratio (5.71) and was noted significantly superior over all other treatments. This might be due to higher production and market prices of vegetable cowpea. Profitability depends on duration of crop and net returns. There has been positive correlation between net returns and system profitability. Highest net returns in vegetable cowpea system are attributed to higher system profitability, mainly due to less production cost, better crop yield and higher prices of vegetable cowpea (Nagoli *et al.* 2017). Significantly higher economic efficiency was recorded in finger millet+horse gram (₹595/ha) system over all other treatments. Minimum crop profitability was found in sole rice (₹39.4/ha). Maximum relative economic efficiency was recorded with finger millet+ horse gram production system and the minimum with black gram.

Competitive indices

Land equivalent ratio (LER) and area time equivalent ratio (ATER): Rice+black gram intercropping recorded highest LER (2.42), being significantly better to sole cropping at par with finger millet+horse gram (2.16) and rice+horse gram (2.14). Rice+black gram with higher ATER (2.68) was noted significantly higher over rest of cropping systems (Table 3). Lower ATER was recorded in sole rice cropping system. Increasing intercropping significantly enhanced ATER, indicating an improvement in per day productivity of rice+black gram with diversified production system. Aggresivity index was recorded positive with rice+black gram (0.22). Their positive/greater values compared with sole crop confirmed aggressivity, competitiveness and dominance of intercropping over sole

Table 3 Various cropping system indices of diversified production system under rainfed agro-ecosystem of eastern hill and plateau hill region

Treatment	LER	ATER	AI	MAI	LUE (%)	SYI (%)	SVI (%)	CO (t CEY/ha)	CEY (t/ha)
Rice sole	1.00	1.00	-	-	0.27	0.09	0.06	3.00	1.20
Finger millet sole	1.00	1.00	-	-	0.38	0.37	0.48	5.43	2.56
Blackgram sole	1.00	1.00	-	-	0.24	0.54	0.34	1.78	1.08
Horse gram sole	1.00	1.00	-	-	0.41	0.48	0.34	1.98	1.24
Vegetable cowpea sole	1.00	1.00	-	-	0.24	0.94	0.75	5.26	5.46
Pigeon pea sole	1.00	1.00	-	-	0.42	0.76	0.82	6.35	1.76
Rice + Blackgram (1:1)	2.42	1.57	0.22	105303	0.27	0.34	0.49	5.25	2.78
Rice + Horse gram (1:1)	2.14	1.53	-0.37	97569	0.41	0.35	0.49	4.93	2.61
Finger millet + Blackgram (1:1)	1.98	1.67	-0.10	125293	0.38	0.42	0.81	7.34	3.55
Finger millet + Horse gram (1:1)	2.16	1.79	-0.19	153100	0.42	0.46	0.95	8.90	3.98
LSD (P=0.05)	0.13	0.12	-	-	0.03	0.04	0.06	0.40	0.34

Mean data of 4 years. LER, land equivalent ratio; ATER, area time equivalent ratio; AI, aggressively index; MAI, monetary advantage index; LUE, land use efficiency; SYI, sustainability yield index; SVI, sustainability value index; CO, carbon output; CEO, carbohydrate equivalent yield.

in intercropping. Higher monetary advantage was recorded with finger millet+horse gram system (₹153100/ha). Results are in agreement with those of Shrikant *et al*. (2014). Land use efficiency was recorded more with pigeonpea and finger millet+horsegram (0.42). Maximum SYI (0.94) was noted with vegetable cowpea system and minimum in sole rice cropping (0.09). Highest SYI (0.95) was recorded in finger millet+horse gram diversified production system.

Thus, while considering diversified production system, finger millet+horsegram intercropping (1:1) was recorded to achieve better in land utilization, maximum system productivity and monetary advantage under rainfed agro-ecosystem of hill and plateau region of eastern India.

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