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Research Article

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Studies on Growth, Productivity and Economics of Rice as Influenced by Diversification of Rice-Based Cropping Systems in Red and Lateritic Soil of West Bengal

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Abstract

The field experiments were conducted at Agricultural farm of the Institute during 2014-15 and 2015-16 to study growth, yield attributes, yield and economics of rice as influenced by rice-based cropping systems. The experiment, consisted of ten treatments, was laid out in Randomised Block Design with each treatment replicated thrice. Growth attributes of rice were influenced significantly by diversification of crops in various rice-based cropping systems. Rice in rice–lentil–elephant foot yam showed highest growth attributes followed by rice–frenchbean–baby corn and rice–yellow sarson–greengram systems though they were at par with each other. Rice in rice–potato–greengram system exhibited highest number of paniclesm^{-2} and filled grains panicle^{-1} followed by rice–lentil–elephant footyam and rice–frenchbean–baby corn system being at par with each other. Highest grain and straw yield of rice was achieved from rice–potato–greengram (4.81 and 6.12 t ha^{-1}, respectively) followed by rice–yellow sarson–greengram and rice–lentil-okra. Gross return, net return and return per rupee investment in rice were not significant during first year but significant response was found during second year where highest gross return, net return and return per rupee investment was found from rice–potato–green gram system (₹ 86,417 ha^{-1}, ₹ 52,099 ha^{-1} and ₹ 2.20, respectively) followed by rice–lentil–okra and rice–yellow sarson-greengram though they were at par with each other. Inclusion of legume crops in rice–based cropping systems enhanced grain and straw yield of rice resulting in higher return from the system.

Keywords: Rice, crop diversification, cropping system, growth, yield, economics

1. Introduction

Cropping systems based on rice (*Oryza sativa* L.) are prevalent in the eastern part of India, which covers 43% of rice area in the country. Rice–based systems are intimately connected with development of water resources. In this era shrinking resource base of land, water and energy, resource-use efficiency is important aspect for considering the suitability of a cropping system (Yadav et al., 2002). The crops are emerging as an alternative option for replacing rice in rice–based cropping systems in water-scarcity areas of north–west part of India and in area, where sowing

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of wheat is delayed after rice and also for enhancing resource–use efficiency (Gupta et al., 2002). Crop diversification would fulfil the basic needs of cereals, pulses, tuber crops and oil seeds (Kumar et al., 2008). Continuous adoption of a particular cropping system has led to the problems of specific weeds, reduced soil fertility and similar kinds of insect pest attack which resulted in declining the efficiency and productivity of the system (Kumar and Yadav, 2005). Crop where treatments were not significant diversification, can play a pivotal role in augmenting the farm incomes/ unit area by utilizing the fallow land for short term vegetables or cash crops. The horizontal/ vertical diversification is now a days relevant under small holder production systems and is having the potential for increasing the production and economics due to high cropping intensity through addition of low volume high value crops over the existing rice- wheat cropping systems. Diversification of cropping systems is necessary to get higher yield and return, to maintain soil health, preserve environment and meet daily requirement of human and animals. Thus, not only the number of crops but the type of crops included in the cropping sequence are also important and dependence on cereal crops need to be shifted to other food crops like potato, vegetables, root crops, pulse and oil seeds (Samui et al., 2004). Hence, an attempt was made to evaluate location specific cropping system for red and lateritic soil of West Bengal with a view to utilize resources judiciously to maximize the return safe to the environment. Diversification and intensification of rice-based system to increase productivity per unit resource is very pertinent. As rice is synonymous with life of the people of eastern India, any modification to the existing system with a tendency to decline the productivity of rice crop will neither be sustainable nor acceptable to the farming community. Hence, choice of the component crops needs to be suitably harvest the synergism among them towards efficient utilization of resource base and to increase overall productivity (Anderson, 2005, Chitale et al., 2011 and Sharma et al. 2014). Higher grain yield of rice from the sequences with summer green manure or pulse crop was also reported by Kumar *et al*. (2001), Hussain et al. (1999); Regmi et al. (2002); Ladha et al. (2003); Hossain et al. (2016) and Weller et al. (2016).

2. Materials and Methods

The field experiments were conducted during 2014–15 and 2015–16 at Agricultural farm (situated at 23^0 39′ N latitude, $87^0$42′ E longitude at an elevation of 58.9 m above mean sea level) Institute of Agriculture, Visva-Bharati, Sriniketan, West Bengal during *kharif, rabi* and *summer* seasons of 2014–15 and 2015–16. The soil of the experimental site was sandy loam in texture, acidic in nature (pH 5.18), low in organic carbon (0.44%), available nitrogen (132.13 kg N ha^{-1}) and phosphorus (25.13 kg P_2O_5 ha^{-1}) and medium in available potassium (107.15 kg K_2O ha^{-1}) content. The experiment, consisted of ten cropping systems, was laid out in Randomized Block Design where each treatment was replicated thrice. Treatments were T_1, Rice-yellow sarson–baby corn; T_2, Rice–yellow sarson–greengram; T_3, Rice–potato–greengram; T_4, Rice–potato–sesame; T_5, Rice–french bean–baby corn; T_6, Rice–french bean–okra; T_7, Rice–baby corn–sesame; T_8, Rice–baby corn–elephant foot yam; T_9, Rice–lentil–elephant footyam; T_{10}, Rice–lentil–okra. A recommended dose of fertilizers (80:40:40 kg of N: P_2O_5:K_2O kg ha^{-1}) was applied in rice where one-fourth of total nitrogen, entire P_2O_5 and half of K_2O was applied as basal. Top dressing of the remaining nitrogen was done in two splits; half of nitrogen at active tillering stage and one fourth nitrogen and half of potassium at panicle initiation stage in rice. Rice (variety MTU 1010) with 25 days old seedlings were transplanted with a spacing of 20 cm ×15 cm with 2-3 seedlings $hill^{-1}$ on July 01, and July 02, during both the years of 2014 and 2015, respectively. The rice crop was raised under rainfed and irrigated condition and *rabi* and *summer* crops were raised under irrigated condition following proper package of practices. *Rabi* crops of potato (var. Kufri – Jyoti), french bean (var. Push Parvati), lentil (var. Ranjan), baby corn (var. Hybrid-Hm4) and yellow sarson var. B-9) were sown during 1^{st} week of October, 2014-15 and 2015-16 and harvested during last week of December, 2014-15 and 2015-16. Summer crops like elephant footyam (var. Gajendra), baby corn var. Hybrid-Hm_4), green gram (var. Samrat), okra (var. Hybrid-F_1) and sesame (var. Roma) were sown during first week of February, 2014-15 and 2015-16, respectively and harvested during last week of June 2014-15 and 2015-16. Observations were recorded for various growth attributes, yield attributes and yield of rice. Standard statistical methods were followed for analysing the experimental data (Gomez and Gomez, 1984).

3. Results and Discussion

3.1. Growth attributes of rice

During 2014 and 2015 growth attributes of rice (viz. LAI, dry matter accumulation and crop growth rate) at different growth stages were influenced significantly by crop diversification in various rice–based cropping systems (Table 1). The highest LAI of rice was observed at 60 DAT (4.49) and a decreasing trend was noticed thereafter (Figure 1). The highest dry matter accumulation (960.1 g m^{-2}) and crop growth rate (20.1 g m^{-2} day^{-1}) were found in rice at 90 DAT and 60-75 DAT, respectively (Figure 2 and Figure 3). However, crop growth rate decreased at later stage (75-90 DAT). Among different rice–based cropping systems, rice in rice–lentil–elephant foot yam system showed highest growth attributes (LAI, dry matter accumulation and crop growth rate). This was followed by rice in rice–French bean–baby corn and rice–rapeseed-green gram. However, these cropping systems were at par with each other. All these systems also produced higher grain and straw yields of rice, which might be attributed to the beneficial effect of legumes grown in summer season (Quayyam and Maniruzzamam, 1996). Since this system is heavily dependent on precipitation

Table 1: Response of crop diversification in rice-based cropping systems on yield components, grain yield, straw yield and harvest index (HI) of kharif rice (pooled data of 2014 and 2015)

Treatment	Yield components			Grain yield (t ha^{-1})			Straw yield (t ha^{-1})			Harvest Index (%)		
	No. of panicles m^{-2}	No. of filled grains panicle^{-1}	Test weight (g)	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled
T_1	363	110	23.1	4.20	4.29	4.25	5.35	5.18	5.27	43.98	45.44	44.71
T_2	397	113	23.1	4.25	5.08	4.67	5.41	6.17	5.78	44.02	45.24	44.63
T_3	400	116	22.8	4.30	5.32	4.81	5.53	6.70	6.12	43.75	44.20	43.98
T_4	381	111	23.3	4.19	4.41	4.30	5.43	5.54	5.54	43.55	43.83	43.69
T_5	395	114	23.4	4.32	4.61	4.47	5.37	5.47	5.46	44.57	45.39	44.98
T_6	388	111	23.9	4.19	4.66	4.43	5.50	5.81	5.66	43.28	44.46	43.87
T_7	389	113	22.8	4.28	4.42	4.35	5.42	5.60	5.51	44.14	44.14	44.14
T_8	366	109	24.2	4.17	4.33	4.25	5.29	5.64	5.38	43.89	44.19	44.04
T_9	400	115	23.3	4.38	4.87	4.63	5.52	5.91	5.72	44.27	45.16	44.72
T_{10}	367	112	23.5	4.09	5.18	4.64	5.34	6.15	5.76	43.26	45.71	44.49
SEm±	5.96	2.35	0.44	0.21	0.23	0.14	0.18	0.27	0.18	0.373	0.462	0.296
CD (p=0.05)	17.72	6.98	NS	NS	0.70	0.42	NS	0.81	0.54	1.107	1.371	0.852

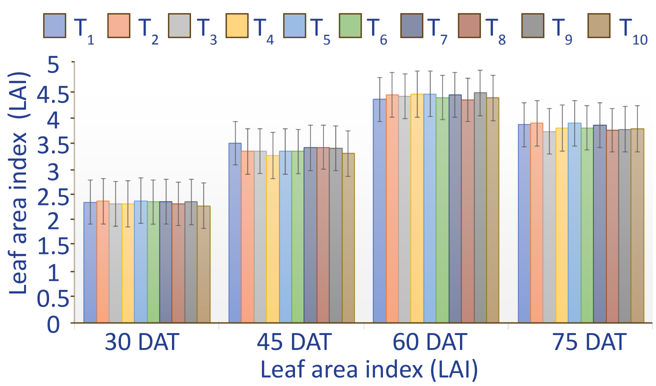

Figure 1: Leaf area index (LAI)

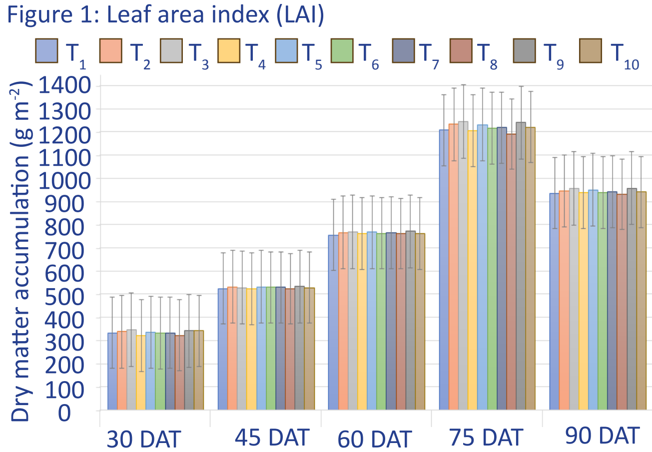

Figure 2: Dry matter accumulation (g m^{-2})

input, upland rice yields is highly variable within different parts of South Asia. The system also suffers from the lowest yield across the globe. There is a risk of crop failure attributed to weed competition, periodic drought, disease incidence,

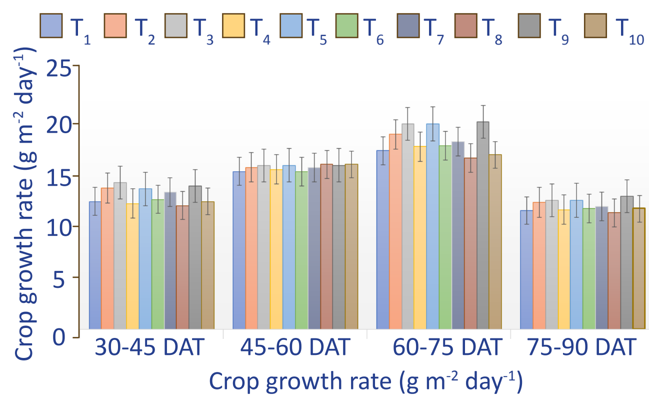

Figure 3: Crop growth rate (g m^{-2} day^{-1})

and soil acidity or infertility (Bista et al. 2010; Seck et al., 2012). The legumes were potentially important to diversify cereal based mono cropping into cereal-legume sequences which had nutrient cycling advantages also reported that Porpavai et al. (2011) and Kanwarkamla (2000) concluded that cultivation of legume crops were viewed more as a soil fertility improver than as independent crops grown for their grain output. This is because legume crops are self-sufficient in N supply. Singh et al. (1997) reported that multiple cropping systems with legumes offer special advantage to farmer. Similar results have also been reported by Saroch et al. (2005).

3.2. Yield components and yield of rice

A significant response was found from crop diversification in rice–based cropping system on yield components of rice viz. number of panicles m^{-2}, number of filled grains panicle^{-1}) except test weight which was not significant. Among different rice–based cropping systems, the highest number of panicles m^{-2} (400) and number of filled grains panicle^{-1} (116) was found from rice in rice–potato–green gram system (Table 1). This was followed by rice in rice–lentil–elephant foot yam and rice–french bean–baby corn. However, these treatments were statistically at par with each other. During first year of experiment (2014), grain and straw yield of rice were not influenced significantly by crop diversification in rice-based cropping systems but in second year (*kharif*, 2015) as well as in pooled data, grain and straw yield of rice were influenced significantly through introduction of various crops in rice–based cropping systems. The highest grain and straw yield (4.81 and 6.12 t ha^{-1}, respectively) was achieved from rice in rice–potato–greengram system followed by rice–yellow sarson–greengram (4.67 and 5.78 t ha^{-1}, respectively) and rice–lentil–okra (4.64 and 5.76 t ha^{-1}, respectively) system on pooled data basis (Table 1). These treatments were at par with each other. Grain and straw yield of rice were not influenced significantly when grown in rice–yellow sarson–baby corn, rice–potato–sesame, rice–baby corn–sesame and rice–baby corn–elephant foot yam. Inclusion of legume crops in rice–based cropping systems enhanced yield components of rice resulting in higher yield when compound with non–legume crops in the systems. Harvest index of rice was influenced significantly due to crop diversification in different rice–based cropping systems where rice in rice–French bean–baby corn showed the highest harvest index (44.98%) followed by rice–lentil–elephant foot yam (44.72%) and rice–yellow sarson–baby corn (44.71%). Inclusion of greengram in the cropping system might have increased the productivity and profitability of rice in rice–potato–greengram system which was in conformity with the findings of Gangwar and Ram (2005) and Singh et al. (2007). Continuous rice cropping is an intensive farming practice in which a rice cultivated in the rainy season (planted in June/ July) is followed by one or two more rice crops in a year depending on the availability of irrigation water and length of the growing season. In this system, rice crop is either transplanted or direct seeded, and heavily supplied with nitrogen fertilizers (Bronson et al., 1998) which contributes to approximately 76% of the global rice production (Fageria et al., 2011), and occupies 7% of the total area and 17% of total agricultural production in South Asia (FAO**,** 2013).

4. Economics

During two consecutive years of field experimentation on crop diversification in different rice–based cropping systems, gross return, net return and return per rupee investment in rice were not significant during first year (2014-2015) of experiment as well as in pooled data (Table 2). However, during second year (2015-2016) of experiment, a significant response was found from introduction of different crops in various rice–based cropping systems on gross return, net return and return per rupee investment in *kharif* rice. Rice in rice–potato–greengram showed the highest gross return (₹ 88,417 ha^{-1}), net return (₹ 52,099 ha^{-1}) and return per rupee investment (₹ 2.20) during second year of experiment followed by rice–lentil–okra (₹ 86,017 ha^{-1}, ₹ 49,699 ha^{-1} and ₹ 2.14, respectively) and rice–yellow sarson–greengram (₹ 84,410 ha^{-1},₹ 48,092 ha^{-1} and ₹ 2.12, respectively) which were at par with each other. Inclusion of legume crops in rice–based cropping systems might have positive influence in increasing the yield of rice resulting in higher gross return, net return and return per rupee investment in rice.

Table 2: Response of crop diversification in different rice-based cropping systems on economics of kharif rice (pooled data of 2014 and 2015)

Treatment	Gross return (₹ ha^{-1})			Net return (₹ ha^{-1})			Return per rupee invested (₹)		
	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled
T_1	69875	71177	70526	33557	34859	34208	1.92	1.96	1.94
T_2	70758	84410	77584	34440	48092	41266	1.95	2.32	2.14
T_3	71620	88417	80019	35302	52099	43701	1.97	2.43	2.20
T_4	69755	73328	73169	33437	37010	36851	1.92	2.02	1.97
T_5	71807	76532	72543	35489	40214	36225	1.98	2.11	2.04
T_6	69842	77410	73626	33524	41092	37308	1.92	2.13	2.03
T_7	71188	73573	72381	34870	37255	36063	1.96	2.03	1.99
T_8	69367	72013	70690	33049	35695	34372	1.91	1.98	1.95
T_9	72892	80822	76857	36574	44504	40539	2.01	2.23	2.12
T_{10}	68162	86017	77090	31844	49699	40772	1.88	2.37	2.12
SEm±	3513.69	3817.20	2594.08	3513.69	3817.20	2594.08	0.097	0.105	0.07
CD (p=0.05)	NS	11340.21	NS	NS	11340.21	NS	NS	0.31	NS

[1US $ = INR 61.56 as on September 29, 2014 & INR 65.837 as on September 29, 2015]

Mishra et al. (2007) also mentioned higher productivity and profitability with inclusion of vegetables and pulses in rice–based cropping systems.

5. Conclusion

Among different crop diversification in rice-based cropping systems, rice in rice-lentil-elephant footyam showed highest growth attributes like leaf area index, dry matter and crop growth rate. The highest yield components number of panicles m^{-2} and number of filled grains $panicle^{-1}$, grain yield and straw yield of rice was achieved from rice-potato-green gram system followed, by rice-yellow sarson-greengram and rice-lentil- okra. Rice-potato-greengram system also fetched highest gross return, net return and return per rupee investment in *kharif* rice.

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