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Effect of intercropping aerobic rice with leafy vegetables on crop growth, yield and its economic efficiency

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Aerobic rice production system provides a sustainable alternative to the traditional rice cultivation. To evaluate the agronomic and economic effect of intercropping aerobic rice with four leafy vegetables, field experiments were conducted at University of Agriculture Science Bangalore research station, India during 2017 and 2018. The experiments consisted of 9 treatments with 4 replications and, a Randomized Completely Block Design was applied. The treatments were as follows: Intercropping (IC_1): rice+amaranth; IC_2: rice + coriander; IC_3: rice + spinach, and IC_4: rice + fenugreek plus other 5 treatments of solecrops (SC), SC_5: rice, SC_6: amaranth, SC_7: coriander, SC_8: spinach, and SC_9: fenugreek. Results showed that intercropping produced significantly better plant growth and higher yields than sole crops. The rice-spinach intercrop produced highest rice grain yield (7,651 kg ha^{-1}), vegetable yield (25,508 kg ha^{-1}), land equivalent ratio (2.13), rice equivalent yield (16,153 kg ha^{-1}), production efficiency (107.69 kg day^{-1}), area time equivalent ratio (1.23) and system harvest index (0.77). Net return and benefit cost ratio of rice-spinach intercropping were also higher than that of sole crops. This suggests that intercropping of aerobic rice with leafy vegetables can be productive and economically efficient.

Key words: Aerobic rice, intercropping, leafy vegetables, productivity.

INTRODUCTION

Rice is the second most widely cultivated cereal after corn and is staple food for more than half of world's population (CGIAR, 2016). Asia-Pacific region produces and consumes over 90% of world rice (Nirmala, 2017). In many parts of the world, rice is predominantly transplanted and flood-irrigated with standing water throughout the season. In Asia especially China and India, 75% of harvested rice is irrigated and lowland type. The

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flooded rice production system is usually preferred as a weed management strategy (Shaibu et al., 2015). Due to present day water resource crisis and high demand for irrigation of other crops, aerobic rice production has been introduced and adopted in several countries including India (Kadiyala et al., 2012; Priyanka et al., 2012).

Aerobic rice is a lowland rice planting system that involves growing drought tolerant high yielding rice varieties in non-flooded soils and with no puddling (Bouman and Toung, 2001; Patel et al., 2010). The aerobic rice has low water requirement as compared to lowland rice and can save about 45% water (Lampayan et al., 2010). Besides being water saver, aerobic rice production is often affected by several abiotic and biotic stress factors such as nutrient deficiencies (Jiban et al., 2019), nematodes (Kreye et al., 2009) and high weed pressure (Anwar et al., 2010; Kumalasari and Bergmeier, 2014). Consequently, these conditions lower yield potential of aerobic rice leading to heavy losses.

Intercropping is a practice that involves growing of two or more crop species at the same time in a field, and is traditionally used as an important strategy in sustainable agriculture (Bybee-Finley and Ryan, 2018). Intercropping is known to increase crop yields, reduce pests and disease and suppress weeds. To explore the potential of intercropping, aerobic rice has also been intercropped with other crops. For instance in Nigeria, farmers intercropped upland rice with cassava and vegetables (Okonji et al., 2012). Jadeyegowda et al. (2019) evaluated different aerobic rice intercropping systems and their effect on rice growth and yield. Intercropping of aerobic rice with watermelon alleviate *Fusarium* wilt by restraining spore formation and improving soil heath (Ren et al., 2008). Increased crop biomass helped in suppressing weed in aerobic rice when intercropped with vegetables (Habimana et al., 2019). The objectives of this study were to assess the effect of intercropping aerobic rice with leafy vegetables on growth, yield and to assess its economic efficiency.

MATERIALS AND METHODS

This study was conducted during two consecutive summer seasons in 2017 and 2018 at research experimental station of University of Agricultural Sciences, Bangalore (UASB), India. The experiment was laid out following RCBD design with nine treatments and four replications. The treatments were: Intercropping (IC_1): rice+amaranth, IC_2: rice + coriander, IC_3: rice+spinach, and IC_4: rice + fenugreek. The remaining 5 treatments were sole crops (SC), namely: SC_5: rice, SC_6: amaranth, SC_7: coriander, SC_8: spinach, and SC_9: fenugreek. Farmyard manure was applied to all plots at a rate of 10 tonnes ha^{-1} 15 days before sowing. The rice and vegetable seeds were directly sown into the soil and common fertilizers such as urea, single superphosphate and muriate of potash were applied. The experimental site had red sandy loam soil with pH 6.7, organic carbon 0.58%, available N 362 kg ha^{-1}, available P 43 kg ha^{-1} and available K 289 kg ha^{-1}. Anaerobic rice genotype MAS946-1 was used in this study. All treatments were managed until maturity and data were collected using five plant samples.

To compare performance of sole rice treatments with the other leafy vegetable intercrops, data on growth, yield and yield attributes were recorded and pooled for 2017 and 2018 and averages were examined through Least Significant Difference (LSD) test at 5% degree of significance. Leafy vegetable, rice grain and straw yield were expressed in ha^{-1} before the analysis of variance (ANOVA). The productivity of intercropping was examined by calculating several parameters. The Land Equivalent Ratio is used to decide which crop is suitable. It denotes relative land area under sole crop required to produce the same yield as obtained under a mixed or an intercropping system at the same level of management. It is the ratio of land required by pure crop to produce the same yield as intercrop. Land Equivalent Ratio (LER) was calculated following Willey (1979). Rice equivalent yield (REY) refers to the yields of different intercrops/crops which are converted into equivalent yield of any one crop based on price of the produce. This was calculated by considering the grain yield of component crops and the existing market price of aerobic rice crop and leafy vegetables components as following Verma and Modgal (1983). Based on REY and duration of the cropping system, production efficiency (PE) was also calculated and expressed as kg day^{-1} according to Habimana et al., (2019). It was based on the rice equivalent yield and duration of cropping system. Area time equivalent ratio (ATER) provides more realistic comparison of the yield of intercropping over monocropping in terms of time taken by component crops in the intercrop. It was used to compare yield advantages of intercropping components over a stand-alone cropping system, and was calculated following Hiebsch and Macollam (1980). The data on the system harvest index (SHI) in the intercropping experiment of rice-leafy vegetables was calculated as following:

$$\text{SHI} = \frac{\text{The economic yield of main crop + Economic yield of intercrop per unit area}}{\text{The biological yield of main crop + Biological yield of intercrop per unit area}}$$

To evaluate economic performance of different intercropping systems, gross and net returns were estimated as of Sujan et al., (2017a, b) in their studies. Benefit cost ratio (BCR) of components crop yield was calculated following the calculation of Bala et al. (2020), Sujan et al. (2021), and Sahota and Malhi (2012).

RESULTS AND DISCUSSION

Growth, yield and yield attributes of rice under intercropping system

Results for rice growth parameters, rice yield attributes, grain yield and straw yield have shown significant difference among the treatments (Table 1). Plant growth, rice grain yield (7,651 kg ha^{-1}) and straw yield (9,687 kg ha^{-1}) were highest in the IC_3 (rice + spinach), whereas rice sole crop showed lowest plant growth, yield, yield attributes and straw yield as compared to the intercrops (Table 1). The higher amount of rice grain yield in IC_3 could be as a result of better yield attributing characters such as number of productive rice tillers per hill (34.10), total number of grain per panicle (160.54) and thousand grain weight (23.72 g). Good performance of the IC_3 could

Table 1. Growth, yield, yield attributes of rice-leafy vegetables intercropping systems (Pooled data of 2017 and 2018).

Treatment	Plant height (cm)	No. of tillers hill^{-1}	TDM (g plant^{-1})	No. of productive tillers hill^{-1}	Total No. of grain panicle^{-1}	1000 grain wt. (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Vegetable yield (kg ha^{-1})
IC_1	67.71	35.3	136.96	31.17	144.14	21.11	6242	8275	14029
IC_2	61.42	31.91	116.23	25.99	125.27	18.39	5731	7936	11642
IC_3	71.22	38.49	150.4	34.1	160.54	23.72	7651	9687	25508
IC_4	64.11	33.11	125.29	29.9	137.48	19.74	6044	8103	13095
SC_5	57.29	28.88	110.55	25.6	119.64	16.94	5691	7278	-
SC_6	-	-	-	-	-	-	-	-	18708
SC_7	-	-	-	-	-	-	-	-	14784
SC_8	-	-	-	-	-	-	-	-	32405
SC_9	-	-	-	-	-	-	-	-	17318
S.Em.±	0.335	0.8	7.35	0.28	2.1	0.3	130.36	259.68	1426
CD (P=0.05)	1.043	2.4	22.9	0.9	6.56	0.95	406.15	809.03	4189

TDM: Total dry matter; S.Em: standard error of mean; CD: critical difference.

be attributed to better growth performance (Table 1). Besides, the large canopy of spinach produced minimum weed population in those plots, which increased the equilibrium thus benefiting the crop in maximum utilization of the accessible resources such as increased soil moisture availability during intercrop period. These results are in conformity with the findings of Mian et al., (2010).

Yield of leafy vegetables

Under intercropping, the yield of amaranth, coriander, spinach and fenugreek were 14029, 11642, 25508 and 13095 kg ha^{-1}, respectively (Table 1). However, when planted as a sole crop, leafy vegetables produced higher yield than when intercropped. The reduction in yield could be as a result of competition for resources during intercropping hence indicating that rice crop was dominant over the leafy vegetables (Oroka and Omororegie, 2007).

Rice equivalent yield (REY) and other efficiencies

All intercropping efficiencies, land equivalent ratio (LER), rice equivalent yield (REY), production efficiency (PE), area time equivalent ratio (ATER) and system harvest index (SHI) were significantly different among the treatments (Table 2). The LERs for all types of intercrops were higher than sole crop, thus indicating that intercropping rice crop with leaf vegetables was more beneficial than sole rice production. This is indicated by better growth and grain yield advantage (80-113%), which is exhibited under intercropping as indicated in Table 1. Higher LER could be due to better use of natural resources as previously indicated by Jabbar et al. (2009) and Udhaya and Kuzhanthaivel (2015). The REYs were higher in all the intercrops with rice-spinach intercrop producing the highest REY (16,153 kg ha^{-1}) (Table 2). High REY indicate the increased productivity in intercrops as compared to sole crop. These results confer with previous studies of Nagwa et al. (2014) and Rayhan et al. (2014). The maximum PE (107.69 kg day^{-1}) was found in rice-spinach intercrop. The findings showed that the intercrops components stayed in the field for a short time and leaf yields were also high resulting to high biomass production per day. Ibni et al. (2005) and Nazrul and Shaheb (2014) reported similar findings. The ATER values showed an average up to 23% in intercropping combination comparison with the sole rice cropping pattern. Intercropping rice with spinach also produced highest ATER of 1.23. Similar trends were reported in research studies of Mian et al., (2011) and Nagwa et al., (2014). The SHI, all intercrops showed higher values and HI of 0.42 for the sole rice crop. These results confer with the findings of Hugar and Palled (2008), Jabbar et al., (2009) and Mohan (2012).

Economic efficiency

Highest gross return (2,56,842 Indian Rupees (INR) ha^{-1}), net returns (INR 212,860 ha^{-1}), and benefit cost ratio (BCR = 5.84) were obtained when rice was intercropped with spinach (Table 3). Both sole rice crop and spinach produced lower gross return, net return and BCR as compared to rice-spinach combination. BCR increased in IC_3 mainly due to the increase in rice grain and straw yield under intercropping system. High aerobic rice yield

Table 2. Yield of companion crops, REY and other efficiencies under rice-leafy vegetables intercropping systems (Pooled data of 2017 and 2018).

Treatment	REY (kg day^{-1})	LER	ATER	SHI	PE (kg day^{-1})
IC_1	10919	1.85	1.04	0.71	72.79
IC_2	9611	1.8	0.97	0.69	64.08
IC_3	16153	2.13	1.23	0.77	107.69
IC_4	10409	1.83	1.01	0.7	69.39
SC_5	-	-	-	-	-
SC_6	-	-	-	-	-
SC_7	-	-	-	-	-
SC_8	-	-	-	-	-
SC_9	-	-	-	-	-
S.Em.±	702	0.08	0.021	0.009	4.12
CD (P=0.05)	2278	0.24	0.066	0.029	12.85

Rice equivalent yield (REY), land equivalent ratio (LER), area time equivalent ratio (ATER), system harvest index (SHI), production efficiency (PE).

Table 3. Economic efficiency of rice-leafy vegetables intercropping systems (Pooled data of 2017 and 2018).

Treatment	Gross returns (₹ha^{-1})	Net returns (₹ha^{-1})	Benefit cost ratio
IC_1	172228	131971	4.28
IC_2	156798	114541	3.71
IC_3	256842	212860	5.84
IC_4	169725	127688	4.04
SC_5	96348	56591	2.42
SC_6	93548	80558	7.2
SC_7	74271	59281	4.95
SC_8	162024	145309	9.69
SC_9	92214	77444	6.24

and leaf yield of vegetables, which in turn increased gross and net returns. Generally, intercropping was economically efficient as compared to sole crops. Similar results were also reported in pea-maize intercropping systems (Yang et al., 2018).

Conclusion

The results of this study showed that all four intercropping combination treatments were appropriate in relation to the stand-alone aerobic rice crop and leafy vegetable treatments. However, aerobic rice intercropping with spinach leafy vegetable has exhibited high production and economic efficiency with respect to biological yield, intercropping efficiencies and benefit cost ratio. Hence, intercropping could be recommended to aerobic rice growers in the studied area.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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