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BIO-ECONOMICS OF DIFFERENT DRY DIRECT SEEDED WINTER RICE BASED INTERCROPPING SYSTEMS UNDER VARYING FERTILIZER MANAGEMENT

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Abstract

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during February to June 2017 to study the feasibility of different direct seeded rice based intercropping systems under varying fertilizer management. The experiment was conducted in afactorialrandomized complete block design with three replications. Four leafy vegetables *viz*., gimakalmi, Indian spinach, red amaranth andjute were intercropped with dry direct seeded boro rice (cv. BRRI dhan28) following three fertilizer dose such as 100, 75 and 125% of recommended fertilizer, and sole rice was also maintained as control. Rice yield was the highest (3.87t ha^{-1}) in sole cropping, and intercroppingresulted insignificant rice yield reduction. Although inintercropping rice yielddecreased, but increased both gross margin and benefit cost ratio (BCR) as compared to rice sole cropping. Among the vegetables, gimakalmi performed the best followed by red amaranth in terms of yield and 125% recommended fertilizer was the best fertilizer dose. Gimakalmi intercropped with rice following 125% recommended fertilizer showed the highest gross return and BCR (2.53). Therefore, vegetables like gimakalmi and red amaranth couldbe recommended as intercrop with dry direct seeded winter rice with 125% recommended fertilizer for better productivity and higher economicreturn.

Introduction

Among field crops, rice is most widely grown under irrigated condition requiring about 50% of the total amount of water diverted for irrigation, which itself accounts for 80% of the amount of fresh water consumed(Farooq *et al.,* 2009). Dry direct seeding rice is considered as a water saving technology having some advantages over puddled transplanted system (Humphreys *et al.*, 2005; Zhao *et al.*, 2007; Anwar *et al.*, 2012; Rahman, 2019).If winter rice is grown following dry direct seeded system, 40-60% irrigation water (compared with traditional flood irrigated system) could be saved (Anwar *et al.*, 2010; Rahman *et al*., 2017; Arefin*et al.*, 2018). In dry direct seeded system, rice is direct seeded on dry soil and moisture content of rice field is kept around or below field capacity. Fortunately, field condition of dry direct seeded rice is favorable for growing different vegetables as intercrop. Therefore, intercropping in direct seeded rice with vegetables may be considered as a viable option to maximize productivity and economic return (Rabeya*et al.*, 2018).

In intercropping system, proper use of fertilizer is very important to ensure the maximum harvest of both main and intercrop. Optimum rate of fertilizer plays a vital role in growth and development of rice plant(Miah *et al.*, 2017; Sarker*et al.*, 2018; Jahan*et al.*, 2018). Rice growth is remarkably hampered when fertilized with lower dose which drastically reduces yield. Potential yieldof a crop can be achieved only when the nutrients are applied at optimum dose which is required by the crop plants.On the other hand, excessive fertilization encourages excessive vegetative growth which makes the plant susceptible to insect, pest and diseases and ultimately reduces yield. So, it is essential to find out the optimum rate of fertilizer application for better productivity and higher economic return of rice - vegetable intercropping systems. But no work has so far been done on this aspect. The present study was thereforeconducted to evaluate the productivity and profitability of different dry direct seeded winter rice based intercropping systems under varying fertilizer levels, and to optimize fertilizer requirement for this system.

Materials and Methods

The experiment was carried out at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh(24°75′ N latitude and 90°50′ E longitude and at an altitude of 18 m), during February to June 2017. The experimental field was medium high land under the agro-ecological zone of Old Brahmaputra Floodplain (AEZ-9).The field was medium high land having well-drained silty loam floodplain soil with pH 6.8.The average air temperature, rainfall (monthly total), relative humidity (monthly average) and sunshine hours (monthly total) during the experimental period ranged from 22.1-28.8°C, 0.20–496.1 mm, 74.7–84.9% and 97.8–191.6 hr.,respectively.The experiment included 2 factors; factor A: intercropping systems (5)such as (i) rice (sole), (ii) rice + gimakalmi, (iii) rice + Indian spinach, (iv) rice + red amaranth, (v) rice + jute,and factor B: fertilizer management (3)such as (i) 100% of recommended fertilizer (RF)for rice, (ii) 75% RF, (iii) 125%RF.Sole leafy vegetable plots ofgimakalmi, Indian spinach, red amaranth and jute were also maintained only for calculating land equivalent ratio.The experiment was laid out in afactorial randomized complete block design (RCBD) with three replications. The unit plot size was 4.0 m × 4.0 m. A brief description of the crop varieties used in this experiment is given in Table 1.

Table 1.Characteristics of the crop varieties

Crop	Cultivar/ variety	Days to harvest	Yield (t ha^{-1})	Developed/ marketed by
Rice (*Oryza sativa*)	BRRI dhan28	133-136	5-6	BRRI
Gimakalmi (*Ipomoea reptans*)	Evergreen 25	20-30	40-45	Metal Seed Ltd.
Indian spinach (*Basella alba*)	Read Leaf	35-40	20-25	Metal Seed Ltd.
Red amaranth (*Amaranthuscruentus*)	Altapeti-20	30-35	9-10	LalTeer Seed Ltd.
Jute (*Corchoruscapsularis*)	CVL-1	30-35	7-8	BJRI

BRRI = Bangladesh Rice Research Institute, BJRI = Bangladesh Jute Research Institute

The land was dry ploughed followed by harrowing and leveling without puddling to obtain a smooth seedbed. Recommended fertilizer dose were 300, 125, 80, 80 kg ha^{-1} of urea, triple super phosphate, muriate of potash and gypsum (100%), respectively. All fertilizers except urea were applied as basal dose. Urea was top dressed in three equal splits at 15, 30 and 45 days after sowing (DAS). The plots were fertilized as per treatments. Sprouted rice seeds were sown on 13 February 2017 in75 cm wide alternate strip in each plot. Red amaranth, jute, gimakalmi, Indian spinach were seeded as intercrop between two rice strips. In rice, spacing was maintained as 15 cm×15 cm. Jute and red amaranth were broadcast while gimakalmi and Indian spinach were sown in line maintaining 25 cm×25 cm and 37.5 cm×15 cm spacing. Seed rate used for jute, gimakalmi, Indian spinach, red amaranth were 8, 9, 12, 2.5 kg ha^{-1}, respectively. Red amaranth and jute seeds were sown twice at the same day of rice sowing and at 35 days after rice sowing. While, gimakalmi and Indian spinach were sown once at the same day of rice sowing. A light irrigation was given just after sowing for proper seed germination and better seedling establishment. Anothertwo irrigations were given at 30 and 60 DAS. After every irrigation excess water was drained out immediately to avoid damage to vegetables. No major disease infestation was noticed either in rice or in vegetables. Only Cup 50 EC was sprayed @20 ml10 L^{-1} water at 40 DAS to prevent cutworm infestation in vegetables.Grain yield was recorded after harvesting the whole plot and was converted to tha^{-1} (14% moisture content).Leafy vegetables were harvested at maturity and fresh weight was taken immediately after harvest and converted to t ha^{-1}.All non-material and material costs constituted the variable cost were considered. Eight working hours of a labor was considered as a man-day, irrigation cost, cost of seed, fertilizer cost etc. were included in variable cost. Gross return was computed by adding market values of grain yield, straw yield and vegetable yield together.

Gross margin = Gross return–Total Variable cost… … … … … … … … (i)

The relative yield of a crop = $\frac{\text{Yield of component crops}}{\text{Yield of sole crop}}$ … … … … … … (ii)

Rice equivalent yield (for vegetables) = $Y_r + \frac{Y_{int} \times P_{int}}{P_r}$… … … … … … … (iii)

Here, Y_r = Yield of rice, P_r= sales price of rice, Y_{int} = yield of intercrop (jute, gimakalmi, Indian spinach and red amaranth), P_{int} = sale price of intercrop

Land equivalent ratio =$\frac{\text{Intercrop yield of rice}}{\text{Sole yield of rice}} + \frac{\text{Intercrop yield of vegetable}}{\text{Sole yield of vegetable}}$ … … … (iv)

Benefit cost ratio (BCR) = $\frac{\text{Gross income}}{\text{Total cost}}$ … … … … … … … … … … … (v)

The collected datawere analyzed using "Analysis of Variance" technique with the help of computer package, MSTAT-C, and the significance of themean differences was adjudged by the Duncan's Multiple Range Test.

Results and Discussion

Rice yield parameters

Among the yield parameters, effective tillers $hill^{-1}$ and grains $panicle^{-1}$ were significantly affected by intercropping systems and fertilizer management but 1000-grain weightinsignificant (Table 2).Intercropping with jute and Indian spinach showed no adverse effect on effective tiller and grain production, but with gimakalmi and red amaranth resulted in reduced number of effective tillers $hill^{-1}$ and grains $panicle^{-1}$ compared to rice sole culture. Both effective tillers $hill^{-1}$ and grains $panicle^{-1}$was gradually increased with the increasing level of fertilizer application.

Rice yield

Grain yield of rice was significantly affected by intercropping system, fertilizer management (Table 2) and their interaction (Table 3). Highest rice yield was obtained from sole culture and intercropping resulted in significant yield reduction. Rice yield was drastically reduced when intercropped with gimakalmi or red amaranth (>46%), while jute and Indian spinach intercropping resulted in around 30% yield reduction. Results showed that rice yield was increased gradually with the every increment of fertilizer rates which confirms demand of higher than recommended fertilizers while intercropping. Among the interactions, sole rice coupled with 125% RF yielded the highest followed by 100 and 75% RF. The lowest grain yield was recorded when gimakalmi was intercropped with rice at 75% recommended fertilizer which was statistically similar to red amaranth intercropped rice following 75% recommended fertilizer.

Table 2.Effect of intercropping systems on yield contributing characters and yield of rice

Intercropping systems	Effective tillers hill^{-1}(no.)	Grains panicle^{-1}(no.)	1000- grain weight (g)	Grain yield (t ha^{-1})
Rice sole	8.15a	83.09a	19.23	3.32a
Rice +gimakalmi	7.167b	79.60b	19.41	1.78d
Rice +Indian spinach	8.02a	82.92a	19.42	2.38b
Rice + red amaranth	7.22b	80.69b	19.17	1.79d
Rice + jute	7.76a	83.26a	19.42	2.23c
$S\bar{x}$	0.14	0.93	0.21	0.03
Level of significance	**	*	NS	**
CV (%)	5.81	3.42	3.36	3.64
Fertilizer management				
100% RF	7.88b	83.34b	19.47	2.44b
75% RF	6.41c	76.55c	19.29	1.74c
125% RF	8.70a	85.85a	19.23	2.72a
$S\bar{x}$	0.11	0.72	0.16	0.02
Level of significance	**	**	NS	**
CV (%)	5.81	3.42	3.36	3.64

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT). ** Significant at 1% level of probability, * =Significant at 5% level of probability, NS = Not significant.

Vegetable yield

Intercropping system, fertilizer management andtheir interaction exerted influence on vegetable yield (Figure 1, 2 and 3).Gimakalmi produced the highest yield closely followed by red amaranth, while Indian spinach yielded the lowest. Like rice, vegetable yield was increased gradually with the increasing level of fertilizer.Among the interactions, the maximum vegetable yield (7.03 t ha^{-1}) was recorded in gimakalmi intercropped with rice at 125% RF which was statistically similar to that of same vegetable grown with 100% RF or red amaranth fertilized with 125%RF. The lowest vegetable yield (0.90 t ha^{-1})was obtained from Indian spinach applied with 75%RF which was statistically similar to those of Indianspinach grown with 100% RF or jutewith 75%RF.

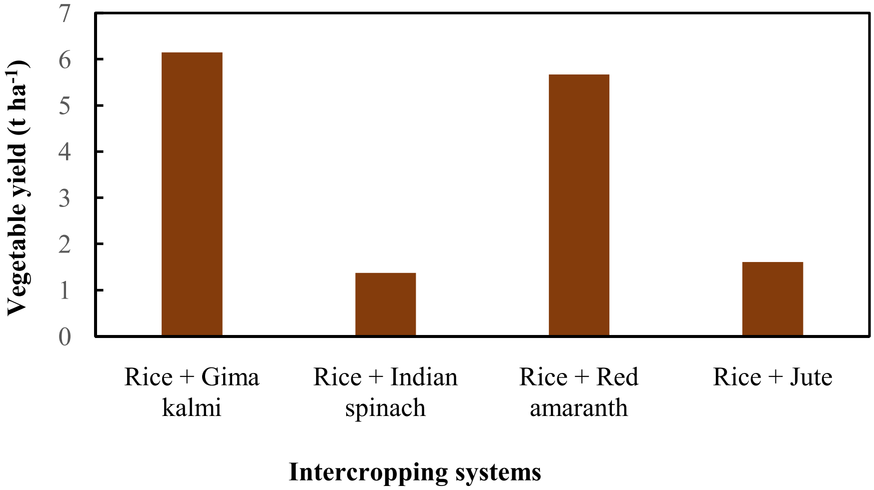

Fig. 1. Effect of intercropping systems on vegetable yield

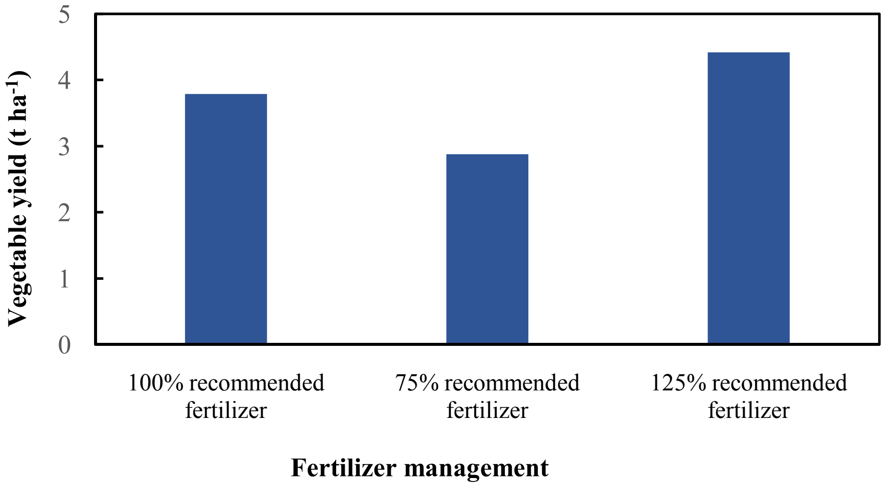

Fig. 2. Effect of fertilizer management onvegetable yield

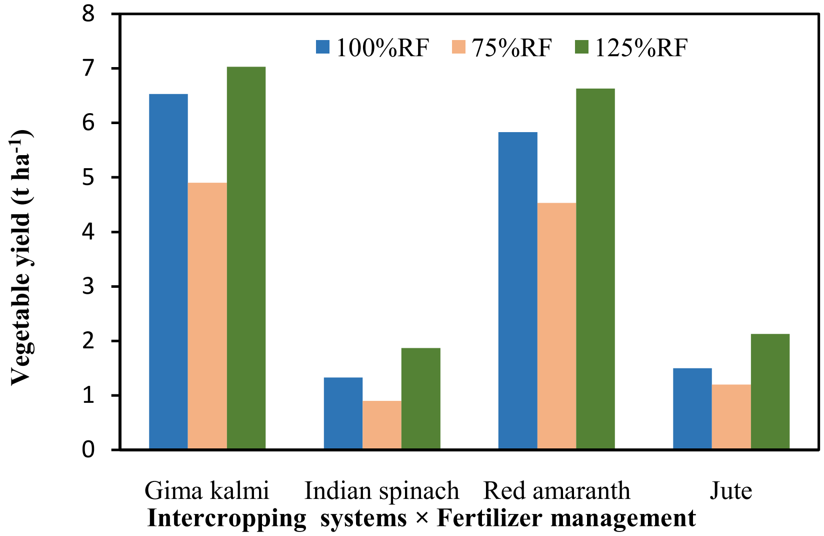

Fig.3. Yield of Vegetables as influenced by intercropping systems and fertilizer management interaction

Relative yield of rice (RYR)

Relative yield determines competitive ability of component crops in intercropping system. As shown in Table 3, the relative yield of rice ranged from 0.44 to 0.75, which indicates that rice yield loss was reduced by around 60% due to intercropping with different vegetables. The highest yield reduction (63%) with of rice was occurred when gimakalmiwas intercropped with rice following 75% recommended fertilizer. On the other hand, the lowest yield reduction (16%) was recorded in rice sole cropping following 125%recommended fertilizer.

Table 3.Rice yield, vegetable yield, relative yield of rice, equivalent yield and land equivalent ratio of intercropping systemsunder different fertilizer management

Interaction		**Yield of rice(tha^{-1})**	**Vegetable yield (tha^{-1})**	**RYR**	**REY (tha^{-1})**	**LER**
0% RF	Sole rice	3.33b	-	-	3.33	1.0
	Rice + gimakalmi	1.89fg	6.53	0.57	7.33	1.11
	Rice + Indian spinach	2.50d	1.33	0.75	3.83	1.3
	Rice + red amaranth	2.03f	5.83	0.61	6.89	1.13
	Jute	2.47d	1.50	0.74	3.97	1.32
75% RF	Sole rice	2.77c	-	-	2.77	1.0
	Rice + gimakalmi	1.23i	4.90	0.44	5.31	0.97
	Rice + Indian spinach	1.87g	0.90	0.66	2.77	1.28
	Rice + red amaranth	1.33i	4.53	0.48	5.11	1.02
	Rice + jute	1.53h	1.20	0.55	2.73	1.15
125% RF	Sole rice	3.87a	-	-	3.87	1.00
	Rice + gimakalmi	2.23e	7.03	0.58	8.09	1.09
	Rice + Indian spinach	2.77c	1.87	0.72	4.64	1.28
	Rice + red amaranth	2.03f	6.63	0.52	7.56	1.05
	Rice + jute	2.70c	2.13	0.70	4.83	1.26

Rice equivalent yield (REY)
Table 3 showed that highest rice equivalent yield (8.09 t ha^{-1}) was obtained from gimakalmiintercropping following125% RF, while the lowest one (2.73 t ha^{-1}) was observed in jute intercropping following 75% RF. Although relative yield of rice was lower than sole crop in every case, but intercropping resulted in higher yield advantage over the sole rice cropping ranged from 18.0 to 142.9%.

Land equivalent ratio (LER)
Land equivalent ratio (LER) was recorded more than 1 for all the intercropping systems except Rice + gimakalmi intercropping with75% RF (Table 3). The LER >1 confirms the advantages of intercropping as compared to sole cropping, while LER < 1 indicates a disadvantage of intercropping. The highest LER of 1.32 (Jute + rice following100% RF) means an intercrop benefit of 0.32. On the contrary, gimakalmi + rice intercropping following 75% RF resulted in the lowest LER of 0.97 with an intercrop loss of 0.03.

Cost benefit analysis
Total variable cost, gross return, gross margin and benefit cost ratio (BCR) of different rice vegetable intercropping systems are presented in Table 3. Total variable cost was less in sole rice cropping following 75% RF than that of other intercrop combinations. The highest total variable cost was calculated (Tk.100850 ha^{-1}) for gimakalmiintercropped with rice following 125% RF because of higher fertilizer dose. The total variable cost for red amaranth and jute were Tk.98525 ha^{-1}and Tk.92675 ha^{-1} at 100%RF, respectively. Indian spinach, on the other hand resulted in the lowest total variable cost of Tk.90325ha^{-1} due to less seed rate and only onetime sowing. Data showed that the lowest gross return was calculated in sole rice. Among the intercrop species, gimakalmiintercropped with rice resulted in the highest gross return (Tk.166550 ha^{-1} to Tk.255300 ha^{-1}) because of highest yield. On the contrary, rice intercropping with jute resulted in the lowest gross return (Tk. 90750ha^{-1}) as well as gross margin (Tk. 2400 ha^{-1}) in jute-rice intercropping system following 75%RF(Table 4). Among the intercrop species, gimakalmiintercropped with rice resulted in the highestgross margin(Tk.154450ha^{-1}) at 125%RF. The highest (2.53) benefit-cost ratio(BCR) was obtained from gimakalmiintercropped with rice following125%RF. Second highest BCR (2.39) was obtained from red amaranth intercropped with rice following125%RF. The lowest BCR (1.03)was found in rice intercropping with jute following 75%RF.

All the yield contributing characters except 1000-grain weight were significantly affected by intercropping systems. Similar to tillering ability, intercropping with gimakalmior red amaranth adversely affected the yield contributing characters of rice. Rice grain yield was significantly reduced in all the intercropping systems but with gimakalmior red amaranth resulted in drastic yield reduction because of the poor performances of yield parameters.Reduction in rice productivity due to intercropping has also been reported by many others (Singh *et al*., 1996; Rabeya*et al*., 2018). Rice yield reduction was mostly the consequence of reduced number of effective tillers hill^{-1} and grains panicle^{-1} and increased number of non-effective tillers hill^{-1}. As reported by many researchers (Ahmad, 1990; Saleem*et al*., 2000),suppressive effect of intercrop species on rice growth and yield attributes was the consequence of inter-specific competition for limited resources during early growth stage and also the incompetence of rice plants to recuperate that loss at later stages. The drastic reduction in rice productivity due to intercropping with gimakalmior red amaranth was mostly the outcome of luxuriant growth and shading effect of those vegetables on rice at early growth stage. Yield of vegetables varied widely and this was happened due to the differences in their yield potential and competitive abilities with rice.

Fertilizer management showed tremendous influence on growth, yield parameters and yield of rice, and all the parameters were gradually improved with the increasing fertilizer rates. Irrespective of intercropping system, rice yield was the highest when fertilized with 125% recommended fertilizer. Even sole rice yield also was increased with the increased fertilizer rates which indicates the poor fertility status of the experimental soil, and also confirms that the recommended fertilizer rate was not enough for the experimental field or study area. Mbah*et al.* (2007) observed that system productivity of the soybean-maize intercropping was increased with the increasing level of fertilizers. Usman *et al.* (2015) also reported similar findings from their study. Although different intercropping systems resulted in substantial rice yield losses, but the system productivity was increased. This might be the consequence of more efficient uses of resources due to varying plant architecture and growth duration of the component crops (Oroka and Omoregie, 2007). Rabeya*et al.* (2018)also reported similar findings from their study done at the same location with same intercropping systems. Competitive behavior and aggressivity of intercrop component are mostly responsible for the yield reduction of main crop (Sullivan, 2001; Muoncke*et al*., 2007). Therefore, selection of intercrop species is very crucial for maximizing the system productivity.

All the intercropping systems yielded higher than rice sole-cropping in terms of rice equivalent yield in this study. Increase in rice equivalent yield due to intercropping has also been reported earlier (Joshi, 2002; Jabbar*et al*., 2010).Land equivalent ratio (LER) were also recorded>1 for all the intercropping systems (except for gimakalmifertilized with 75% RF) which endorses the advantages of intercropping over sole cropping of rice. Differences in the yielding ability among vegetable species might be responsible for the variation in LER among different intercropping systems (Rabeya*et al.,* 2018). Higher bio-efficiency in terms of LER in intercropping has also been documented by many researchers (Oroka and Omoregie, 2007; Ogutu*et al.,* 2012). All the intercropping systems resulted in higher net return and benefit cost ratio than rice sole cropping. These results are in conformity with those of many researchers (Saleem*et al*., 2000; Rabeya*et al*., 2018). This might be due to the higher yield along with higher market price of vegetables compared to those of rice.

Table 4. Cost and return analysis of rice-leafy vegetable intercropping systems under differentfertilizer management

Interaction		Gross return (Tk. ha^{-1})	Total variable cost (Tk.ha^{-1})	Grossmargin (Tk.ha^{-1})	BCR
100% RF	Sole rice	117550	84925	32625	1.38
	Rice + gimakalmi	231450	99575	131875	2.32
	Rice + Indian spinach	129050	90325	38725	1.43
	Rice + red amaranth	218000	98525	119475	2.21
	Rice + jute	133100	92675	40425	1.44
75% RF	Sole rice	98100	80600	17500	1.22
	Rice + gimakalmi	166550	95250	71300	1.75
	Rice + Indian spinach	93750	86000	7750	1.09
	Rice + red amaranth	160800	94200	66600	1.71
	Rice + jute	90750	88350	2400	1.03
125% RF	Sole rice	136750	86200	50550	1.59
	Rice + gimakalmi	255300	100850	154450	2.53
	Rice + Indian spinach	154350	91600	62750	1.69
	Rice + red amaranth	238150	99800	138350	2.39
	Rice + jute	160050	93950	66100	1.70

Present study confirms the viability of cultivating leafy winter vegetables as intercrop with dry direct seeded winter rice. It is also evident that rice-vegetable intercropping results in better productivity and higher economic return compared to rice sole cropping. Based on the present findings, gimakalmi or red amaranth could be suggested as potential intercrop component of dry direct seeded winter rice. However, further site specific studies considering other agronomic and fertilizer requirement of dry direct seeded rice-leafy vegetable intercropping system aspects are necessary. Hence, it deserves further investigation to formulate the fertilizer package for different dry direct seeded rice-leafy vegetable intercropping systems.

Conclusion

Findings of the present study confirm the feasibility of intercropping leafy vegetables especially gimakalmi and red amaranth in dry direct seeded boro rice.Although intercropping diminished rice yield, but increased both gross marginand benefit cost ratioas compared to sole rice cropping. Among the vegetables,gimakalmiperformed the best followed by red amaranth in terms of yield with 125% recommended fertilizer dose. Therefore, rice intercropping withgimakalmi following 125%recommended fertilizer could be practiced for higher profitability.

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