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BIO-ECONOMIC ASSESSMENT OF FODDER MAIZE (*ZEA MAYS*) INTERCROPPED WITH RICEBEAN (*VIGNA UMBELLATA*) UNDER DIFFERENT SPATIAL ARRANGEMENTS AND NUTRIENT MANAGEMENT PRACTICE

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SUMMARY

Fodder cereals and legume-based intercropping play an important role in providing a balanced diet for our livestock. Legumes in fodder cereals play an important role in increasing fodder yield and quality. Furthermore, nutrient management practices in fodder cereal and legume based intercropping helps to achieve optimum production without compromising fodder biomass. As a result, the current study was carried out during the *Kharif* season of 2019 at the Research Farm of the Agronomy Section, ICAR-NDRI, Karnal, to investigate the effect of nutrient management practices on fodder maize and ricebean intercropping. The experimental results revealed a higher value of green fodder yield and dry matter yield in a 1:1 and 2:1 ratio of maize and ricebean intercropping with 100% RDF and PGPR. When maize and ricebeans were grown in a 1:1 ratio with 100% RDF + PGPR, the land equivalent ratio (LER), maize equivalent yield (MEY), and relative crowding coefficient (K) values increased. Furthermore, the monetary returns of maize + ricebean (1:1) with 100% RDF + PGPR application accounted for higher net returns (Rs. 41,969 ha^{-1}) and the maximum B: C ratio (2.27) and proved to be more advantageous than pure stands.

Key words: Fodder, intercropping indices, nutrient management and economics

Livestock and agriculture are interwoven; livestock acts as a cushion to the rural economy, contributing 25.60 per cent to agriculture's GDP and 4.11 per cent to total GDP in the year 2020–21 (Anonymous, 2021). India is gifted with a huge treasure of livestock, with a population of 536.9 million (≈15% of the world's livestock population). The majority of the nutritional demand of livestock is obtained from fodder crops or crop residues left after the harvest, only about 5% of the farmland is used for growing fodder crops. Currently, green and dry fodder are deficient to the extent of 30.6 per cent and 11.95 per cent respectively (Anonymous, 2015). The area under cultivated fodder has remained static for the past 3 – 4 decades and there is less scope for increasing the area under fodder crops (Dagar, 2017). To meet the current fodder demand of our livestock, we need to increase productivity per unit area through crop diversification. Intercropping of leguminous fodder crops with non-leguminous fodder crops can serve a dual purpose by providing quantity along with quality fodder. Intercropping of legumes with fodder cereals helps to supply balanced minerals to the dairy animals, as leguminous fodder crops are superior in their accumulation of minerals such as Ca, Mg, Cu, Zn, Mn and Co in comparison with cereal fodder crops (Juknevicius and Sabiene, 2007). Intercropping of legumes in an additive series helps to increase the productivity and profitability of the entire system. This may be due to some of the speculated advantages of intercropping systems, such as higher fodder yields, greater land-use efficiency and improved soil fertility through symbiotic N fixation in leguminous crops (Ofori and Stern, 1987). Since maize and ricebean are the important fodder crops grown by farmers mainly as a sole crop, the ricebean crop has been neglected and underutilized among the farming community. Hence, considerable efforts need to be made through the development of proper agronomic practices along with nutrient management to introduce ricebean as an intercrop in fodder maize. The fodder maize–legume intercropping system, besides increasing productivity and profitability, also improves soil health, conserves soil moisture and increases total out turn (Padhi and Panigrahi 2006). Spatial arrangement and plant population in an intercropping system have important effects on the balance of competition between component crops and their overall productivity. A number of indices, such as land equivalent ratio, relative crowding coefficient, competitive ratio, actual yield loss, monetary advantage and intercropping advantage, have been proposed to describe competition within intercropping systems (Agegnehu *et al*., 2006; Dhima *et al*., 2007). However, such indices have been used in fodder maize and ricebean intercropping for the assessment of competition among species and also the economic advantages of each intercropping system. Keeping these facts in mind, the current study was designed to expand the possibility of increasing fodder crop production potential per unit area and time basis.

MATERIALS AND METHODS

Site details: Agronomic experiment was performed at Research Farm of Agronomy Section, ICAR-NDRI, Karnal during *Rainy* season of 2019. Geographically, the experimental site situated at 29°45' N latitude, 76°58' E longitude and at an altitude of 245 m above mean sea level (MSL).

Soil status: The soil of an experimental site was neutral in pH (7.24), clay loam in texture, medium in organic carbon (0.62%), low in available N (147.4 kg/ha) and medium in available P (24.5 kg/ha) and K (251.2 kg/ha).

Treatments description: The experiment was laid out in Randomized Block Design (RBD) with 14 treatments*viz*., $T_{1=}$ Maize sole + RDF; $T_{2=}$ Ricebean sole + RDF; $T_{3=}$ Maize + Ricebean (1:1) + RDF; $T_{4=}$ Maize + Ricebean (1:1) + 50% RDF; $T_{5=}$ Maize + Ricebean (1:1) +50% RDF + PGPR; $T_{6=}$ Maize + Ricebean (1:1) + 75% RDF; $T_{7=}$ Maize + Ricebean (1:1) + 75% RDF + PGPR; $T_{8=}$ Maize + Ricebean (1:1) + 100% RDF + PGPR; $T_{9=}$ Maize + Ricebean (2:1) + RDF; $T_{10=}$ Maize + Ricebean (2:1) + 50% RDF; $T_{11=}$ Maize + Ricebean (2:1) + 50% RDF + PGPR; $T_{12=}$ Maize + Ricebean (2:1) + 75% RDF; $T_{13=}$ Maize + Ricebean (2:1) + 75% RDF + PGPR and $T_{14=}$ Maize + Ricebean (2:1) + 100% RDF + PGPR and replicated thrice. The recommended dose of fertilizer for maize i.e., 120:60:40 kg NPK/ha and ricebean i.e., 20:50:20 kg NPK/ha. For sole crops their respective recommended dose of fertilizer was applied whereas, in intercropping we consider the demand of only main crop (maize) and fertilizer varied as per the treatments (100%, 75% and 50% RDF). The fodder maize (Cultivar J-1006) and Ricebean (Sikkim local) were sown with seed rate of 45 and 35 kg/ha during 1st week of August by giving spacing of 30 × 10 cm for sole crop of maize and ricebean. Whereas,

TABLE 1

Green fodder yield as influenced nutrient management and row pattern

Treatments	Green fodder yield (t/ha)			Contribution (%)	
	M	R	Total	M	R
Maize + RDF	34.17[a]		34.17[e]	100	-
Ricebean + RDF	-	15.17[a]	15.17[f]	-	100
M + R (1:1) + RDF	31.07[a-c]	13.02[b]	44.08[ab]	71.36	28.64
M + R (1:1) + 50% RDF	26.40[d]	10.10[c]	36.50[de]	73.92	26.08
M + R (1:1) + 50% RDF + PGPR	27.62[b-d]	10.05[c]	37.67[c-e]	74.35	25.64
M + R (1:1) + 75% RDF	30.17[a-d]	12.00[b]	42.17[a-c]	71.50	28.50
M + R (1:1) + 75% RDF + PGPR	29.67[a-d]	12.52[b]	42.00[a-c]	70.30	29.70
M + R (1:1) + 100% RDF + PGPR	32.00[ab]	13.25[b]	45.25[a]	71.87	28.13
M + R (2:1) + RDF	32.08[ab]	8.25[cd]	40.33[b-d]	80.21	19.79
M + R (2:1) + 50% RDF	27.00[cd]	7.33[d]	34.33[e]	78.11	21.89
M + R (2:1) + 50% RDF + PGPR	27.83[b-d]	7.17[d]	35.00[e]	79.49	20.51
M + R (2:1) + 75% RDF	31.15[a-c]	7.48[d]	38.63[c-e]	81.03	18.97
M + R (2:1) + 75% RDF + PGPR	31.20[a-c]	7.47[d]	38.67[c-e]	81.37	18.62
M + R (2:1) + 100% RDF + PGPR	31.92[ab]	8.58[cd]	40.50[b-d]	79.95	20.05
SEm±	1.34	0.62	1.41	-	-

Note: Means followed by the same letter (s) did not differ significantly by DMRT (p= 0.05)

M- Maize; R- Ricebean; RDF- Recommended dose of fertilizer; PGPR- Plant growth promoting rhizobacteria.

intercropped maize geometry was modified by giving spacing of 45 × 7.5 cm to introduce ricebean. For accommodating component crops in intercropping treatments additive series was used. Forage crops were harvested manually by separating maize and ricebean to determine extra fodder yield obtained from each treatment and dry matter yield estimated based on oven dry weight basis.

Assessment of intercropping efficiency

a. Land equivalent ratio (LER): gives an accurate assessment of the greater biological efficiency of the intercropping situation and was calculated as:

$$LER = (Y_{ab}/Y_{aa}) + (Y_{ba}/Y_{bb})$$

Where: Y_{aa} = Yield of sole crop 'a'; Y_{bb} = Yield of sole crop 'b'; Y_{ab} = Yield of crop 'a' intercropped with crop 'b'; Y_{ba} = Yield of crop 'b' intercropped with crop 'a'. When LER is greater than 1, the intercropping favors the growth and yield of the species. In contrast, when LER is lower than 1, the intercropping negatively affects the growth and yield of plants grown in mixtures (Dhima *et al*., 2007).

b. Maize equivalent yield (MEY): Maize equivalent yield was calculated by considering prevailing market prices of main and inter crops with the following formula:

MEY= (Fodder yield of intercrop/market price of maize) x market price of intercrop.

c. Relative crowding coefficient (RCC): Relative crowding coefficient measures the dominance of one species over the other in a mixture. When the value of RCC is greater than 1, there is a yield advantage. But when it is equal to 1, there is no yield advantage. Relative crowding coefficient was calculated as per the following formula.

$$RCC= [Y_{ab}*Z_{ba} / (Y_{aa}-Y_{ab})* Z_{ab}]$$

Where, Y_{aa} = Yield of component crop 'a' as sole crop; Y_{bb} = Yield of component crop 'b' as sole crop; Y_{ab}= Yield of component crop 'a' as intercrop combination with 'b'; Y_{ba} = Yield of component crop 'b' as intercrop combination with 'a'; Z_{ba} = Sown proportion of component crop 'b' as intercrop combination with 'a'; Z_{ab} = Sown proportion of component crop 'a' as intercrop combination with 'b'.

Economic analysis: The economics of each treatment were worked out on the basis of prevailing market price of inputs and out puts for production and estimated as cost of cultivation, gross return, net return and the benefit: cost ratio.

Statistical analysis: The data were analysed as described by Gomez and Gomez (1984) in MS EXCEL by using DMRT test with SPSS (ver. 20) software.

RESULT AND DISCUSSION

Green fodder yield

The fodder yield is directly related to the genetic potential of a particular variety. Along with a variety, some agronomic interventions adopted during crop production, especially nutrient management practices, play a significant role in determining the yield of a particular crop. Fodder yield under intercropped conditions was significantly influenced by different nutrient management practices (Table 1). Intercropping maize and ricebean in a 1:1 ratio with RDF + PGPR produces more green fodder (45.25 t ha^{-1}) than maize and ricebean alone, and is statistically comparable to T_3 and T_7. Application of PGPR helps reduce the fertilizer demand to the tune of 25 per cent without compromising fodder yield, but the contribution of both crops was less than 100 per cent in comparison with the sole crop (100%). This is due to the partition of available resources among both crops under intercropped cultivation. This might be due to the increased photosynthetic area per unit area, helps to harness more solar energy through its photosynthetic activity, leading to more uptake of nutrients, which in turn increases biomass production. The extra yield contribution from ricebean in the 1:1 additive series eventually increases the fodder yield. Additional fertilizer dose increases have a positive effect on other growth attributes that are directly related to green fodder yield. The results are in tune with Zaman and Malik. (2000) and Kheroar and Patra. (2013).

Dry matter yield

The dry matter yield of sole maize + RDF (85.10 q ha^{-1}) was found to be superior to other treatments, with the exception of T_3 and T_8 at a 1:1 ratio and T_9, T_{13}, and T_{14} at a 2:1 ratio. In ricebean, sole ricebean + RDF yielded significantly higher dry fodder yield (35.70 q ha^{-1}). However, sowing maize + ricebean in a 1:1 ratio with RDF and PGPR resulted in a significantly higher dry matter yield (109.30 q ha^{-1}) than T_{13} and T_{14} treatments in a 2:1 ratio (Fig. 1.). Higher dry matter yield of both maize and ricebean

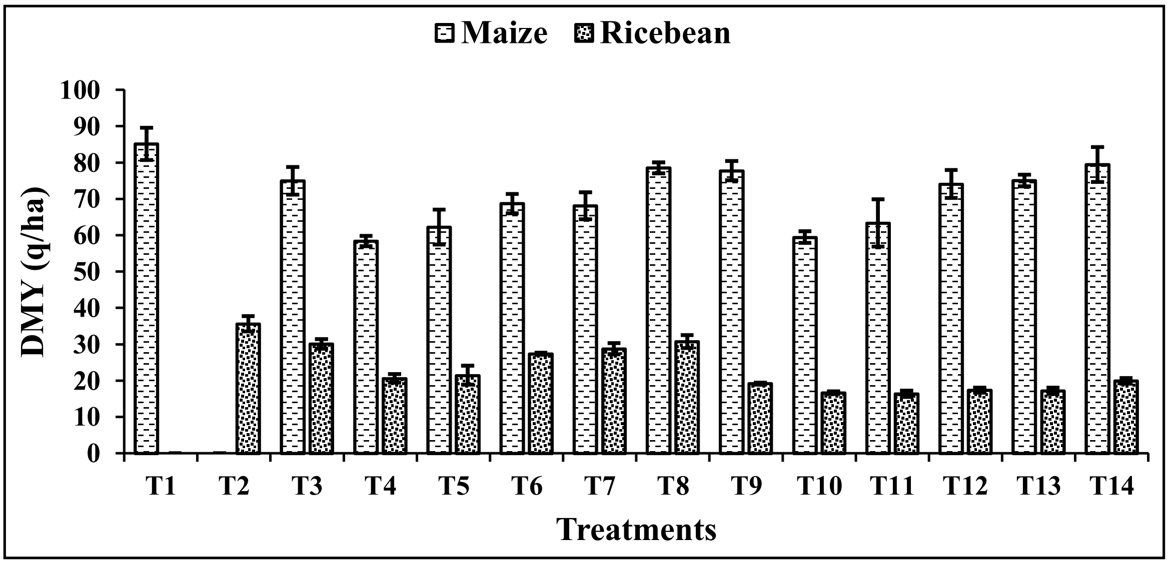

Fig. 1. Effect of Nutrient management practices on dry matter yield (q/ha) in Maize + Ricebean inter-cropping condition.

recorded under sole crop than intercropped condition due to higher dry matter% under sole crop which experienced zero competition from intercrop for available resources, which made the plant grow healthier than intercropped situation, however per plot wise higher dry matter yield was recorded under intercropped treatment as green fodder yield obtained more in comparison to sole crop. The findings are consistent with Surve *et al* (2012).

Maize equivalent yield

The highest maize equivalent yield of green fodder was observed by intercropping fodder maize and ricebean in a 1:1 proportion along with RDF and PGPR (46.91 t/ha), followed by T_3 (45.71 t/ha), T_7 (43.75 t/ha) and T_6 (43.67 t/ha) treatments of a 1:1 ratio with application of RDF and PGPR. This is due to the balanced competition and complementary effects of both crops, allowing for better utilization of available resources. Similar beneficial effects of legume intercropping in relation to higher system productivity and profitability have also been reported by Birbal Sahu (2006) and Rao *et al.* (2009).

Land equivalent ratio

Compared to the sole crop, intercropping of

TABLE 2

Land equivalent ration and Relative crowding coefficient as influenced nutrient management and row pattern

Treatments	MEY (t/ha)	LER			K		
		M	R	Total	K_M	K_R	K_{SY}
Maize + RDF	34.17^{g}	1.00	-	1.00			
Ricebean + RDF	17.06^{h}	-	1.00	1.00			
M + R (1:1) + RDF	45.71^{ab}	0.91	0.86	1.77	10.02^{b}	6.05^{b}	60.67^{b}
M + R (1:1) + 50% RDF	37.76^{e-g}	0.77	0.67	1.44	3.40^{g}	1.99^{f}	6.78f^{g}
M + R (1:1) + 50% RDF + PGPR	38.92^{d-f}	0.81	0.66	1.47	4.22^{f}	1.96^{f}	8.28^{ef}
M + R (1:1) + 75% RDF	43.67^{a-d}	0.88	0.79	1.67	7.54^{c}	3.79^{d}	28.58^{c}
M + R (1:1) + 75% RDF + PGPR	43.75^{a-c}	0.87	0.83	1.69	6.59^{d}	4.72^{c}	31.14^{c}
M + R (1:1) + 100% RDF + PGPR	46.91^{a}	0.94	0.87	1.81	14.77^{a}	6.91^{a}	102.1^{a}
M + R (2:1) + RDF	41.36^{b-e}	0.94	0.54	1.48	7.70^{c}	2.39^{e}	18.37^{d}
M + R (2:1) + 50% RDF	35.25^{fg}	0.79	0.48	1.27	1.88^{h}	1.87^{f}	3.53^{g}
M + R (2:1) + 50% RDF + PGPR	35.90^{fg}	0.81	0.47	1.29	2.20^{h}	1.79^{f}	3.94^{g}
M + R (2:1) + 75% RDF	39.57^{c-f}	0.91	0.49	1.40	5.16^{e}	1.95^{f}	10.06^{e}
M + R (2:1) + 75% RDF + PGPR	39.60^{c-f}	0.91	0.49	1.41	5.26^{e}	1.94^{f}	10.20^{e}
M + R (2:1) + 100% RDF + PGPR	41.57^{b-e}	0.93	0.57	1.50	7.09^{cd}	2.61^{e}	18.49^{d}
SEm±	1.45	-	-	-	0.23	0.11	1.03

*M- Maize; R- Ricebean; K- Relative crowding coffeciency; Sy- System.

TABLE 3
Economics of fodder maize and ricebean under various nutrient management and row pattern

Treatments	Cost of cultivation (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B : C ratio
Maize + RDF	26,108	54,672	27,365	2.09
Ricebean + RDF	23,077	27,306	4,229	1.18
M + R (1:1) + RDF	33,019	73,148	40,129	2.21
M + R (1:1) + 50% RDF	29,943	60,420	30,477	2.02
M + R (1:1) + 50% RDF + PGPR	30,005	62,282	32,277	2.07
M + R (1:1) + 75% RDF	31,480	69,872	38,392	2.21
M + R (1:1) + 75% RDF + PGPR	31,542	70,008	38,466	2.22
M + R (1:1) + 100% RDF + PGPR	33,081	75,050	41,969	2.27
M + R (2:1) + RDF	30,384	66,178	35,794	2.17
M + R (2:1) + 50% RDF	27,308	56,394	29,086	2.06
M + R (2:1) + 50% RDF + PGPR	27,370	57,434	30,064	2.09
M + R (2:1) + 75% RDF	28,873	63,303	34,430	2.19
M + R (2:1) + 75% RDF + PGPR	28,935	63,366	34,431	2.19
M + R (2:1) + 100% RDF + PGPR	30,446	66,516	36,070	2.18

Note: Selling price of fodder maize @ Rs. 1600 per ton and ricebean @ Rs. 1800 per ton.
M- Maize; R- Ricebean; RDF- Recommended dose of fertilizer; PGPR- Plant growth promoting rhizobacteria.

fodder maize with ricebean, irrespective of spatial arrangements, showed land equivalent ratio (LER) values greater than one, indicating higher total productivity of the system and a yield advantage due to intercropping (Table 2.). A higher LER of 1.81 was recorded in T_8 [Maize + Ricebean (1:1) + 100% RDF + PGPR] which is showing superiority among all the intercropping treatments. These results demonstrate that 27–81 per cent more land area is required by a sole crop of maize and ricebean to equal the fodder yield under an intercropped condition, demonstrating greater land-use efficiency than sole maize and ricebean. This might be due the extra yield contribution from ricebean in the 1:1 additive series eventually increases the fodder yield and LER. These results are in conformity with the findings of Agegnehu *et al.* (2006).

Relative crowding coefficient

The RCC value was significantly influenced by row proportion and nutrient management practices. Here, the K value of both fodder maize and ricebean is greater than unity, indicating that both crops have produced a higher fodder yield than the expected yield. Since in all intercropping treatments, the K value of fodder maize is greater than ricebean, this indicates that fodder maize is the dominant species and ricebean is dominated species. The total K was much higher than one in the case of fodder maize + ricebean in a 1:1 ratio with RDF and PGPR which also indicate the yield advantage of the system (Table 1). The higher K value in maize may be due to its greater competitive ability than ricebean. Further increased biomass production per unit area with its large canopy could drastically overcrowd legumes. The results are in tune with Sheoran *et al.* (2010).

ECONOMICS

The ultimate aim of a farmer is to obtain more returns per rupee invested. The data pertaining to the effect of various nutrient management practices on the economics of fodder maize and ricebean are presented in table 3. The highest cultivation cost was observed in Maize + Ricebean (1:1) + 100% RDF + PGPR (Rs. 33,081ha^{-1}), closely followed by Maize + Ricebean (1:1) + RDF (Rs. 33,081 ha^{-1}), owing to the additional seed cost of ricebean and labor. However, in terms of net returns, cultivation of maize + ricebean (1:1) + 100% RDF + PGPR (Rs. 41,969 ha^{-1}) had the highest net returns and sole ricebean + RDF (Rs. 4,229 ha^{-1}) had the lowest. In terms of B:C ratio, the plot with maize and ricebean sown in a 1:1 ratio with RDF + PGPR received higher return rupees per rupee invested (2.27), while sole ricebean produced the least (1.18). In comparison with sole crops, intercropped treatments recorded higher biomass with only an extra cost of ricebean seeds. This might be the possible reason for higher returns and the B: C ratio under intercropped maize and ricebean. Similar findings related to high returns under intercropped situations were also described by Prasanthi (2012) and Zaman and Malik (2000).

CONCLUSION

The current study on the biological and economic feasibility of fodder maize and ricebean intercropping in two ratios (1:1 and 2:1) with varying levels of RDF versus the corresponding pure stands. The results showed that intercropping ricebean with maize, regardless of row arrangements, was beneficial in increasing the system's total productivity and yield advantage by 9.5 -27.15% when compared to sole maize. Specifically, the combined application of 100% RDF and PGPR to maize and ricebean (1:1) intercropping was found to be more remuneration to farmers along with higher value of land use efficiency and least competition among them.

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