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Effect of Brown Manuring on Performance of Rice Bean in Aerobic Rice – Rice Bean Cropping System

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ABSTRACT: The decline in soil fertility resulting from intensive chemical use in modern farming underscores the critical need for sustainable methods like brown manuring. The field experiment was conducted at Agronomy field unit, ZARS, UASB, GKVK, Bengaluru during summer and *kharif* seasons of 2022 and 2023 to study effect of brown manuring on performance of rice bean in aerobic rice – rice bean cropping system. The experiment was composed of three factors *viz.*, factor I: Brown manuring (C_1-Rice and C_2-Rice + Sunhemp), factor II: RDF levels (N_1 - 75% RDF, N_2 - 100% RDF and N_3 - 125% RDF) and factor III: Herbicides [H_1 - No herbicide, H_2 - Pendimethalin (1000 g *a.i.* ha^{-1}) PE *fb* Pyrazosulfuron (25 g *a.i.* ha^{-1}) (POE at 25 DAS) and H_3 - Bensulfuron methyl + Pretilachlor 6.6 % G (660 g *a.i.* ha^{-1}) PE *fb* Bispyribac sodium (25 g *a.i.* ha^{-1}) 25-30 DAS] with total of 18 treatment combinations replicated thrice and laid out in RCBD design with Factorial concept. Rice + sunhemp recorded higher plant height (42.99 cm), dry matter production (25.52 g plant^{-1}), number of pods (44.02plant^{-1}), grain yield (1241 kg ha^{-1}) and haulm yield (2811 kg ha^{-1}). Among different RDF levels, 125% RDF recorded higher plant height (41.96 cm), dry matter production (24.91 g plant^{-1}), number of pods (42.97 plant^{-1}), grain yield (1211 kg ha^{-1}) and haulm yield (2753 kg ha^{-1}). Pre-emergent application of bensulfuron methyl + pretilachlor 6.6 % G (660 g *a.i.*ha^{-1}) *fb* bispyribac sodium (25 g *a.i.*ha^{-1} at 25-30 DAS) noticed higher plant height (41.50 cm), dry matter production (24.64 g plant^{-1}), number of pods (42.50 plant^{-1}), grain yield (1198 kg ha^{-1}) and haulm yield (2727kg ha^{-1}). Combination of rice + sunhemp with 125% RDF along with application of bensulfuron methyl + pretilachlor 6.6 % G (660 g *a.i.*ha^{-1}) *fb* bispyribac sodium (25 g *a.i.*ha^{-1} at 25-30 DAS) recorded higher plant height (44.45 cm), dry matter production (26.39g plant^{-1}), number of pods (45.52 plant^{-1}) grain yield (1283 kg ha^{-1}) and haulm yield (2893 kg ha^{-1}).

Keywords: Brown manuring, Herbicides, Rice bean and yield.

INTRODUCTION

Rice bean (*Vigna umbellate*), a member of the Leguminosae (Fabaceae) family, is an annual underutilized grain legume or pulse is native of south East Asia. It is cultivated in south pacific Islands, Japan, Korea, Africa, Mauritius, USA, and Australia. In India, crop is mainly grown in Tripura, Assam, Manipur, Meghalaya, Nagaland, Arunachal Pradesh, Mizoram, hilly regions of North Bengal and Sikkim. It is attracting attention worldwide owing to its high yielding ability, resistance to viral, fungal, and bacterial diseases. In India, Rice bean is used for both food and fodder (Pattanayak *et al.*, 2019). Legumes in general are scarce, costly, and defective in their nutritional and cooking qualities but rice bean seed protein is varying from 15-25 per cent, crude fat (g/100 g) 0.46 to 0.52 and crude fibre 6.3 to 7.5. The amounts (mg/100 g) of calcium ranged from 280 to 325, sodium 43 to 52, potassium 171 to 210, phosphorus 216 to 275 and iron 6 to 7 (Katoch, 2013). It contains high quality vitamins like thiamine, niacin and riboflavin. Because of its high nutritional qualities, it is considered to be the best pulse crop among all traditional pulses.

Brown manuring, the practice of co-culture of rice + sunhemp, later sunhemp plants are sprayed with selective herbicides like 2, 4-D ester for desiccation of sunhemp plants after 20-25 days of sowing (Tanwar *et al.*, 2010) which holds significant potential in addressing nutrient deficiencies and enhancing soil health in aerobic rice cultivation. Incorporating organic matter through brown manuring enriches the soil with essential nutrients, improves its structure and water-holding capacity, and promotes microbial activity. This practice not only impacts the immediate crop but also leaves behind a lasting influence on subsequent cultivation (Hiremath *et al.*, 2020). Understanding the long-term consequences of brown manuring on pulse is essential for sustainable agricultural practices. This research delves into the enduring impacts of brown manuring on subsequent crops, offering valuable insights into how this eco-friendly technique can contribute to increased productivity and improved soil health.

Understanding these residual effects is crucial for optimizing resource utilization and ensuring food security in an environmentally responsible manner. Therefore, one of the specific objectives of the study was to assess the carry-over effects of brown manuring in combination with different RDF levels and herbicides on performance of residual rice bean in rice - rice bean cropping system.

MATERIAL AND METHODS

The field experiment was conducted at Agronomy field unit, ZARS, UASB, GKVK, Bengaluru. This site is located in AgroClimatic Zone V (Eastern Dry Zone) of Karnataka at a latitude of 13º 05' North, longitude of 77º 34' East and an altitude of 924 m above mean sea level. The soil of the experimental site was red sandy loam in texture and slightly acidic in reaction (pH 6.2) with normal electrical conductivity (0.35 dS m^{-1}) and low in organic carbon content (4.5 mg kg^{-1}). The initial soil nutrient status was medium with respect to available nitrogen (229.5 kg ha^{-1}), phosphorus (26.6 kg ha^{-1}) and potassium (219.5 kg ha^{-1}).

Study was conducted to know the effect of brown manuring on performance of rice bean in aerobic rice – rice bean cropping system during summer and *kharif* seasons of 2022 and 2023. The experiment was composed of three different factors *viz.*, factor I: Brown manuring (C_1-Rice and C_2-Rice + Sunhemp), factor II: RDF levels (N_1- 75% RDF, N_2- 100% RDF and N_3- 125% RDF) and factor III: Herbicides [H_1- No herbicide, H_2- Pendimethalin (1000 g *a.i.* ha^{-1}) PE *fb* Pyrazosulfuron (25 g *a.i.* ha^{-1}) (POE at 25 DAS) and H_3: Bensulfuron methyl + Pretilachlor 6.6 % G (660 g *a.i.* ha^{-1}) PE *fb* Bispyribac sodium (25 g *a.i.* ha^{-1}) 25-30 DAS] and totally with 18 treatment combinations which were replicated thrice and laid out in completely randomised block design (RCBD) with factorial concept. During *kharif* 2022 and 2023 rice variety KMP 175 seeds (5 kg ha^{-1}) were sown with spacing of 25 cm × 25 cm at depth of 4-5 cm and simultaneously sunhemp seeds (25 kg ha^{-1}) were broadcasted in brown manuring plots (rice + sunhemp). Nutrients were applied as per the treatments in the form of urea, single super phosphate and murate of potash to supply nitrogen, phosphorus, and potassium, respectively as per the treatments. The 50 per cent of nitrogen and total amount of phosphorus and potassium were applied at sowing time and remaining 50 per cent of nitrogen was applied as top dressing at 30 and 60 DAS in two equal splits (RDF used is 100: 50: 50 kg ha^{-1} NPK). Pre-emergent herbicides were sprayed at 2 days after sowing and post emergent herbicides were applied at 25-30 days after sowing. Brown manured plots were sprayed with 2, 4-D ester @ 600 ml ha^{-1} at 25 DAS for desiccation of sunhemp plants. After harvest of rice, rice bean was taken as sequential crop to know the residual effect of brown manuring. After harvest of rice the plots were remained as it is without disturbing the soil. Later during *kharif* 2022 and 2023, rice bean was sown with spacing of 30 cm × 10 cm at a depth of 4-5 cm in plots where rice was grown.

Biometric observations on growth parameters were recorded from randomly selected five plants at 30, 60 days after sowing and at harvest in the net plot. Data related to yield was recorded at the time of harvest of the crop. The data recorded on various parameters were subjected to Fisher's method of analysis of variance and interpretation of the data was made as given by Gomez and Gomez (1984). The level of significance used in 'F' and 't' test was P = 0.05. Whenever F-test was significant for comparison amongst the treatments means an appropriate value of critical differences (CD) was worked out. Otherwise against CD values abbreviation 'NS' (Non-significant) is indicated.

RESULTS AND DISCUSSION

A. Growth attributes of rice bean

Pooled data (Table 1) indicated that rice + sunhemp has recorded significantly higher plant height (42.99 cm), number of branches (11.00 $plant^{-1}$) and dry matter production (25.52 g $plant^{-1}$) over sole cultivation of rice at harvest. There was significant increase in plant height with increasing level of RDF. Among different RDF levels, 125% RDF has recorded significantly higher plant height (41.96 cm), number of branches (10.74 $plant^{-1}$) and dry matter production (24.91 g $plant^{-1}$) which was on par with 100% RDF and significantly lower plant height (38.41cm), number of branches (9.83 $plant^{-1}$) and dry matter production (22.80 g $plant^{-1}$) noticed under 75% RDF.

Significantly higher plant height (41.50 cm), dry matter production (24.64 g $plant^{-1}$) and numerically number of branches (10.62 $plant^{-1}$) resulted from pre-emergent application of bensulfuron methyl + pretilachlor 6.6 % G (660 g *a.i.*ha^{-1}) *fb* bispyribac sodium (25 g *a.i.*ha^{-1} at 25-30 DAS) which was on par with pre-emergent application of pendimethalin (1000 g *a.i.*ha^{-1}) *fb* pyrazosulfuron (25g *a.i.*ha^{-1} at 25 DAS) whereas, lower plant height (39.42 cm), number of branches (10.09 $plant^{-1}$) and dry matter production (23.40 g $plant^{-1}$) observed in no herbicide treatment at harvest of the crop. Combination of rice + sunhemp with 125% RDF along with pre-emergent application of bensulfuron methyl + pretilachlor 6.6 % G (660 g *a.i.*ha^{-1}) *fb* bispyribac sodium (25 g *a.i.*ha^{-1} at 25-30 DAS) recorded numerically higher plant height (44.45 cm), number of branches (11.37 $plant^{-1}$) and dry matter production (26.39 g $plant^{-1}$) compared to other treatments combinations.

Increased availability of nutrients in soil due to mineralization of organic nutrient from brown manuring in preceding rice along with beneficial effect of added chemical fertilizers to rice could have triggered cell division, cell elongation and cell multiplication resulting in higher growth rate of shoots in turn increased plant height of rice bean. Similar findings were reported by Nehra and Hooda (2002); Ashwini *et al*. (2015). Additionally, applying a higher level of fertilizers to the preceding rice crop ensures that the soil is adequately nourished which later benefits the subsequent rice bean crop, promoting more robust branching. Thus, combination of these practices in turn synergistically enhanced the growth and development

of the rice bean crop. The results are in line with the findings of Nooli and Chittapur (2001) who reported that the residual effect of organic and inorganic sources of nutrients applied to the rice crop significantly increased the plant height, number of branches per plant, and other growth attributes of lentil crop grown in the same field as residual crop. Higher leaf area aids in more solar radiation interception led to higher dry matter production. Production and distribution of dry matter among the plant parts is very important in regulating crop yield. The results corroborate those of Mahalingam and Sheela (2003); Gopakkali and Sharanappa (2014) and Latha and Sharanappa (2014). These results were also supported by Yadav and Christopher (2006), Deotale *et al*. (2008); Kumar (2009). Residual effect of organics was also noticed by Reddy and Reddy (2005) wherein the plant height, number of leaves, leaf area, yield attributes, and root yield in radish were significantly affected due to the residual effect of vermicompost in onion-radish cropping system.

B. Yield attributes of rice bean

Data pertaining to pod length, number of seeds pod^{-1} and test weight as influenced by residual effect of brown manuring, different RDF levels and herbicides is presented in Fig. 1a and 1b.

Rice + sunhemp recorded significantly higher number of pods (44.02 plant^{-1}), pod length (7.67 cm), number of seeds (7.69 pod^{-1}) and test weight (18.55 g) compared to sole cultivation of rice (39.02 plant^{-1}, 7.98 cm, 6.82 pod^{-1} and 16.44 g, respectively).

Among different levels of RDF, application of 125% RDF has recorded significantly higher number of pods, pod length, number of seeds and test weight (42.97 plant^{-1}, 8.79 cm, 7.51 pod^{-1} and 18.10 g, respectively) which was on par with 100% RDF compared to 75% RDF (39.33 plant^{-1}, 8.04 cm, 6.87 pod^{-1} and 16.57 g, respectively).

Effect of herbicide application on number of seeds pod^{-1} and test weight of rice bean was found non-significant during both the years of study. But significantly higher number of pods (42.50plant^{-1}) and pod length (8.69 cm) were recorded under pre-emergent application of bensulfuron methyl + pretilachlor 6.6 % G (660 g *a.i.* ha^{-1}) *fb* bispyribac sodium (25 g *a.i.* ha^{-1} at 25-30 DAS), which was found to be on par with pre-emergent application of pendimethalin (1000 g *a.i.* ha^{-1}) *fb* pyrazosulfuron (25g *a.i.* ha^{-1} at 25 DAS) whereas, significantly lower number of pods (40.37 plant^{-1}) and pod length (8.25 cm) observed in without herbicide treatment.

Number of pods, pod length, number of seeds pod^{-1} and test weight did not vary among interactions between brown manuring, RDF levels and herbicides but combination of rice + sunhemp with 125% RDF along with pre-emergent application of bensulfuron methyl + pretilachlor 6.6 % G (660 g *a.i.*ha^{-1}) *fb* bispyribac sodium (25 g *a.i.*ha^{-1} at 25-30 DAS) recorded numerically higher number of pods (45.52 plant^{-1}), length of pod (9.31cm), number of seeds (7.95 pod^{-1}) and test weight (19.18 g) compared to other treatments combinations.

Brown manure crops grow densely and quickly, outcompeting weeds for sunlight and nutrients. When these brown manure crops incorporated into the soil, they leave behind a weed-suppressive residue (Farooq *et al*., 2022). Reduced competition for resources and allows the succeeding crop to grow with fewer weed-related stresses, resulting in better yield parameters. Addition to this added nutrient (NPK) through brown manure crop resulted in increased essential nutrient for the promotion of the meristematic and physiological activities, which promotes higher photosynthetic activities leading to production of enough assimilates for subsequent translocation to various sink and there by leading to production of higher sink components like number of pods plant^{-1}, pod length, number of seeds plant^{-1} and test weight and yield. Pulses, like rice bean, have the ability to fix atmospheric nitrogen with the help of nitrogen-fixing bacteria in their root nodules. When residual nitrogen is present in the soil, the pulse crop may reduce its reliance on nitrogen fixation, allocating more energy towards other physiological processes, such as seed development, ultimately boosting yield parameters. Brown manured crops, when incorporated into the soil, add organic matter and nutrients. Similar results were reported by Singh *et al*. (2007); Ramachandran *et al.* (2012); Grewal *et al*. (1992).

C. Grain yield, straw yield and harvest index

The grain yield and haulm yield were significantly influenced by residual effect of brown manuring, RDF levels and herbicides and data presented in Table 2.

Between the brown manuring treatments, rice + sunhemp has recorded significantly higher grain yield (1176 and 1305 kg ha^{-1}), haulm yield (2769 and 2852 kg ha^{-1}) and numerically higher harvest index (0.298 and 0.314 respectively) compared to sole cultivation of rice during 2022 and 2023, respectively.

During 2022 and 2023, application of 125% RDF has recorded significantly higher grain yield (1148 and 1274 kg ha^{-1}, respectively), haulm yield (2712 and 2794 kg ha^{-1}, respectively) and numerically higher harvest index (0.297 and 0.313, respectively) which was on par with application of 100% RDF. While, lower grain yield (1051 and 1166 kg ha^{-1}, respectively), haulm yield (2515 and 2590 kg ha^{-1}, respectively) and harvest index (0.294 and 0.310, respectively) were observed with application of 75% RDF.

Among the different herbicide treatments, significantly higher grain yield (1260 and 1198 kg ha^{-1}) and haulm yield (2767 and 2727 kg ha^{-1}) were recorded under application of bensulfuron methyl + pretilachlor 6.6 % G (660 g *a.i.* ha^{-1}) PE *fb* bispyribac sodium (25 g *a.i.* ha^{-1} at 25-30 DAS) during 2023 and on pooled basis, respectively. This was however on par with application of pendimethalin (1000 g *a.i* ha^{-1}) PE *fb* pyrazosulfuron (25g *a.i* ha^{-1} POE at 25 DAS) whereas, lower grain yield (1197 and 1138 kg ha^{-1}, respectively) and haulm yield (2648 and 2610 kg ha^{-1}, respectively) observed under no herbicide application.

Residual effect of a brown manure crop primarily enhances soil fertility, structure and overall health. This in turn, provides the succeeding crop with improved access to essential nutrients, better water management, reduced competition from weeds, and even some protection from soil-borne diseases and pests. These combined factors contribute to increased yield parameters, yield and improved overall plant health in the succeeding crop. Above results are in line with the findings of Grewal *et al.* (1992). The similar findings were reported by Gangawar *et al.* (2004); Jat *et al.* (2010) who observed that the residual effect of sesbania green manuring + wheat straw and sesbania green manuring alone used in preceding maize affected significantly the growth and yield of succeeding wheat.

Table 1: Effect of brown manuring, RDF levels and herbicides on growth parameters of rice bean in aerobic rice-rice bean cropping system.

Treatment	Plant height (cm)			Number of branches plant^{-1}			Dry matter production (g plant^{-1})		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
Brown manuring (C)									
C_1	37.33	38.89	38.11	9.62	9.88	9.75	21.97	23.28	22.63
C_2	42.10	43.87	42.99	10.85	11.15	11.00	24.78	26.26	25.52
S.Em.±	0.45	0.49	0.46	0.14	0.17	0.13	0.27	0.30	0.29
CD at 5%	1.30	1.35	1.33	0.42	0.48	0.37	0.79	0.87	0.85
RDF level (N)									
N_1	37.62	39.20	38.41	9.70	9.96	9.83	22.14	23.47	22.80
N_2	40.43	42.13	41.28	10.42	10.70	10.56	23.79	25.22	24.51
N_3	41.10	42.83	41.96	10.59	10.88	10.74	24.19	25.64	24.91
S.Em.±	0.55	0.58	0.57	0.14	0.16	0.15	0.33	0.35	0.34
CD at 5%	1.59	1.66	1.62	0.41	0.46	0.44	0.94	0.99	0.96
Herbicides (H)									
H_1	38.61	40.23	39.42	9.95	10.22	10.09	22.72	24.09	23.40
H_2	39.89	41.56	40.72	10.28	10.56	10.42	23.47	24.88	24.18
H_3	40.64	42.35	41.50	10.48	10.76	10.62	23.92	25.35	24.64
S.Em.±	0.55	0.58	0.57	0.14	0.16	0.15	0.33	0.35	0.34
CD at 5%	NS	1.66	1.62	NS	NS	NS	NS	0.99	0.96
Interaction C×N×H									
$C_1N_1H_1$	33.66	35.07	34.37	8.68	8.91	8.79	19.81	21.00	20.40
$C_1N_1H_2$	34.03	35.46	34.74	8.77	9.01	8.89	20.02	21.23	20.63
$C_1N_1H_3$	34.55	36.00	35.27	8.90	9.14	9.02	20.33	21.55	20.94
$C_1N_2H_1$	36.90	38.45	37.67	9.51	9.77	9.64	21.72	23.02	22.37
$C_1N_2H_2$	38.27	39.88	39.07	9.86	10.13	10.00	22.52	23.87	23.20
$C_1N_2H_3$	39.88	41.56	40.72	10.28	10.56	10.42	23.47	24.88	24.17
$C_1N_3H_1$	39.12	40.76	39.94	10.08	10.36	10.22	23.02	24.40	23.71
$C_1N_3H_2$	39.34	40.99	40.17	10.14	10.41	10.28	23.15	24.54	23.85
$C_1N_3H_3$	40.19	41.88	41.04	10.36	10.64	10.50	23.65	25.07	24.36
$C_2N_1H_1$	39.59	41.25	40.42	10.20	10.48	10.34	23.30	24.69	24.00
$C_2N_1H_2$	41.64	43.39	42.52	10.73	11.02	10.88	24.51	25.98	25.24
$C_2N_1H_3$	42.23	44.00	43.12	10.88	11.18	11.03	24.85	26.34	25.60
$C_2N_2H_1$	41.13	42.86	41.99	10.60	10.89	10.74	24.21	25.66	24.93
$C_2N_2H_2$	42.91	44.71	43.81	11.06	11.36	11.21	25.25	26.76	26.01
$C_2N_2H_3$	43.48	45.31	44.40	11.21	11.51	11.36	25.59	27.12	26.36
$C_2N_3H_1$	41.27	43.00	42.14	10.64	10.93	10.78	24.29	25.74	25.02
$C_2N_3H_2$	43.14	44.95	44.04	11.12	11.42	11.27	25.39	26.91	26.15
$C_2N_3H_3$	43.54	45.37	44.45	11.22	11.53	11.37	25.62	27.16	26.39
S.Em.±	1.36	1.41	1.38	0.39	0.36	0.35	0.80	0.85	0.82
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

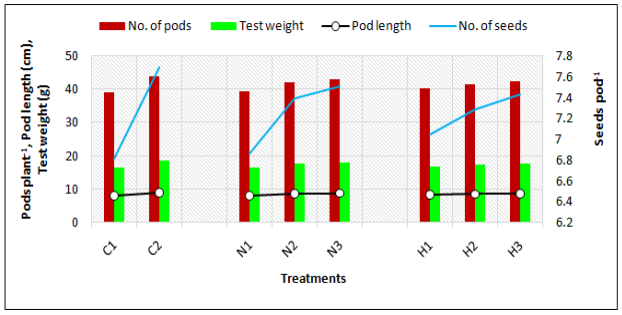

Fig. 1a. Effect of brown manuring, RDF levels and herbicides on yield parameters of rice bean in aerobic rice-rice bean cropping system.

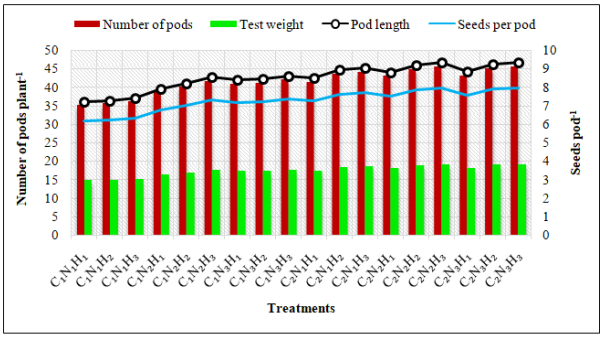

Fig. 1b. Effect of brown manuring, RDF levels and herbicides on yield parameters of rice bean in aerobic rice-rice bean cropping system.

Legend:

Factor-I: Brown manuring	Factor-II: RDF levels	Factor-III: Herbicides
C_1-Rice	N_1-75 % RDF	H_1-No herbicides
C_2-Rice+sunhemp	N_2-100 % RDF	H_2- Pendimethalin (1000 g a.i. ha^{-1}) PE *fb* Pyrazosulfuron (25g a.i. ha^{-1}each) (POE at 25 DAS)
	N_3-125 % RDF	H_3- Bensulfuron methyl + pretilachlor 6.6 % G (660 g a.i. ha^{-1}) PE *fb* Bispyribac sodium (25 g a.i. ha^{-1}) 25-30 DAS

Table 2: Effect of brown manuring, RDF levels and herbicides on grain yield, haulm yield and harvest index of rice bean in aerobic rice-rice bean cropping system.

Treatment	Grain yield (kg ha^{-1})			Haulm yield (kg ha^{-1})			Harvest index		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
Brown manuring (C)									
C_1	1043	1157	1100	2498	2573	2536	0.294	0.310	0.302
C_2	1176	1305	1241	2769	2852	2811	0.298	0.314	0.306
S.Em.±	12.6	14.0	13.3	25.6	26.4	26.0	0.000	0.000	0.000
CD at 5%	36.3	40.3	38.3	73.7	75.9	74.8	0.001	0.002	0.001
RDF level (N)									
N_1	1051	1166	1108	2515	2590	2552	0.294	0.310	0.302
N_2	1129	1253	1191	2674	2754	2714	0.297	0.313	0.305
N_3	1148	1274	1211	2712	2794	2753	0.297	0.313	0.305
S.Em.±	15.5	17.2	16.3	31.4	32.3	31.9	0.001	0.001	0.001
CD at 5%	44.5	49.3	46.9	90.2	92.9	91.6	0.001	0.002	0.002
Herbicides (H)									
H_1	1078	1197	1138	2571	2648	2610	0.295	0.311	0.303
H_2	1114	1237	1175	2643	2723	2683	0.296	0.312	0.304
H_3	1135	1260	1198	2686	2767	2727	0.297	0.313	0.305
S.Em.±	15.5	17.2	16.3	31.4	32.3	31.9	0.001	0.002	0.001
CD at 5%	NS	49.3	46.9	NS	92.9	91.6	NS	NS	NS
Interaction C×N×H									
$C_1N_1H_1$	940	1044	992	2291	2359	2325	0.290	0.305	0.298
$C_1N_1H_2$	950	1055	1003	2311	2381	2346	0.291	0.307	0.299
$C_1N_1H_3$	965	1071	1018	2341	2411	2376	0.292	0.308	0.300
$C_1N_2H_1$	1031	1144	1087	2474	2548	2511	0.294	0.310	0.302
$C_1N_2H_2$	1069	1186	1128	2552	2628	2590	0.295	0.311	0.303
$C_1N_2H_3$	1114	1236	1175	2643	2723	2683	0.296	0.312	0.305
$C_1N_3H_1$	1093	1213	1153	2600	2678	2639	0.296	0.312	0.304
$C_1N_3H_2$	1099	1220	1159	2612	2691	2652	0.296	0.312	0.304
$C_1N_3H_3$	1123	1246	1184	2661	2741	2701	0.297	0.313	0.305
$C_2N_1H_1$	1106	1227	1166	2627	2705	2666	0.296	0.312	0.304
$C_2N_1H_2$	1163	1291	1227	2743	2825	2784	0.298	0.314	0.306
$C_2N_1H_3$	1179	1309	1244	2776	2860	2818	0.298	0.314	0.306
$C_2N_2H_1$	1149	1275	1212	2714	2795	2755	0.297	0.313	0.305
$C_2N_2H_2$	1198	1330	1264	2815	2899	2857	0.299	0.314	0.307
$C_2N_2H_3$	1214	1348	1281	2847	2933	2890	0.299	0.315	0.307
$C_2N_3H_1$	1153	1279	1216	2722	2804	2763	0.297	0.313	0.306
$C_2N_3H_2$	1205	1337	1271	2828	2913	2870	0.299	0.315	0.307
$C_2N_3H_3$	1216	1350	1283	2851	2936	2893	0.299	0.315	0.307
S.Em.±	37.9	42.0	40.0	76.9	79.2	78.0	0.001	0.002	0.001
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

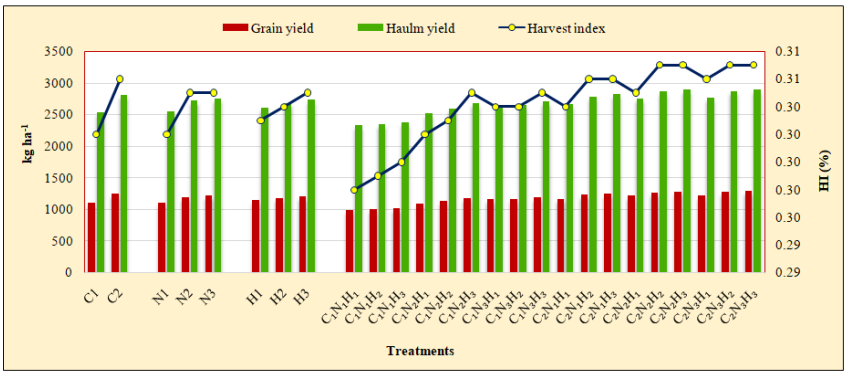

Fig. 2. Effect of brown manuring, RDF levels and herbicides on grain yield, haulm yield and harvest index of rice bean in aerobic rice-rice bean cropping system.

Legend:

Factor-I: Brown manuring	Factor-II: RDF levels	Factor-III: Herbicides
C_1-Rice	N_1-75 % RDF	H_1-No herbicides
C_2-Rice+sunhemp	N_2-100 % RDF	H_2- Pendimethalin (1000 g a.i. ha^{-1}) PE *fb* Pyrazosulfuron (25g a.i. ha^{-1}each) (POE at 25 DAS)
	N_3-125 % RDF	H_3- Bensulfuron methyl + pretilachlor 6.6 % G (660 g a.i. ha^{-1}) PE *fb* Bispyribac sodium (25 g a.i. ha^{-1}) 25-30 DAS

CONCLUSION AND FUTURE SCOPE

Practice of brown manuring (Rice+Sunhemp) in aerobic rice has increased the yield of residual rice bean (12.8 %) grown after rice due to its beneficial effects on soil health and improved nutrient availability to subsequent crops. Application of 125% RDF in rice increased the growth and yield of residual crop. Pre-emergent application of bensulfuron methyl + pretilachlor 6.6 % G (660 g *a.i.*ha^{-1}) *fb* bispyribac sodium (25 g *a.i.*ha^{-1} at 25-30 DAS) had beneficial effect on residual rice bean crop in terms of increasing growth and yield by reducing the weed flora in residual crop.

Farmers can use brown manuring technology due to its multiple benefits *viz.*, reducing weed competition in present crop (rice) and ample supply of nutrients to residual crops (rice bean) like pulses and oil seeds due to its higher nutrient availability in soil after its decomposition, along with this it also improves the physico-chemical and biological properties of soil which reduce the nutrient losses. It also reduces the chemical load (fertilizers and herbicides) to soil. This sustainable practice can help to increase yields, reduce environmental impact and ensure food security in an eco-friendly manner.

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Conflict of Interest. None.

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