Indian Journal of Agronomy **68** (2): 133–139 (June 2023)

Research Paper

Integrated nutrient-management practices effect on productivity of rice (*Oryza sativa*) and soil properties under rainfed lowland rice situation – A long-term study

K. MANJAPPA[1]

Agricultural Research Station on Paddy, University of Agricultural Sciences, Sirsi, Karnataka 581 401

Received: December 2021; Revised accepted: April 2023

ABSTRACT

An experiment was conducted on a fixed site at Agricultural Research Station (Paddy), Sirsi, University of Agricultural Sciences, Dharwad, Karnataka, India, during the rainy (*kharif*) season of 2000 to 2017 (18 years), to study the long-term effect of integrated nutrient-management (INM) practices on productivity of rice (*Oryza sativa* L.) and its soil health. The experiment was laid out in a split-plot design with 7 main plot treatments, viz. no manure, farmyard manure (FYM) @ 10 t/ha, vermicompost @ 5 t/ha, eupatorium @ 10 t/ha, gliricidia [*Gliricidia sepium* (Jacq.) Steud.] or quick stich @ 10 t/ha, sunhemp (*Crotalaria juncea* L.) grown *in-situ* @ 8.96 t/ha and paddy straw @ 5 t/ha) and 3 subplot treatments [no fertilizer, 50% recommended dose of fertilizer (RDF) and 100% RDF]. The average of 18 years pooled data showed that, the grain yield, straw yield and net returns of rice were significantly higher with the application of gliricidia and eupatorium @ 10 t/ha compared to all other manures. Among the interactions of different organic manures and inorganic fertilizers, combinations of application of gliricidia @ 10 t/ha + 100% RDF resulted in significantly higher grain yield (6.2 t/ha), straw yield (7.8 t/ha) and net returns (₹30,569/ha) followed by eupatorium + 100% RDF. The grain yield, straw yield and net returns obtained with application of green-leaf manures, viz. gliricidia alone (5.29, 6.01 t/ha and ₹25,443/ha, respectively) or eupatorium @ 10 t/ha alone were found to be at par with that of 100% RDF alone.

Key Words: Green-leaf manures, INM, Inorganic fertilizers, Organic manures, Rice

Application of organic manures in huge quantities is essential to ensure optimal soil physical condition. But in the present scenario of reduced animal population and deforestation, availability of organic manure has reduced considerably (Prabhudeva *et al.,* 2017). Therefore, sustainable crop production depends on the rational use of chemical fertilizers along with organic manures. Among the rice (*Oryza sativa* L.)-growing countries, India has the largest area and stands second in production. India produces 116.4 million (m) tonnes of rice in an area of 43.7 m ha, with the productivity of 2.66 t/ha during 2019 (MoA&FW, 2020). In hill zone of Karnataka, rice is the major crop grown under rainfed situation but the productivity is low as compared to state average. One of the constraints identified for low yield is inadequate and improper nutrient management.

Imbalanced fertilization through inorganic fertilizer alone could have serious adverse impact on soil health and ultimately on crop yield (Patel *et al*., 2013). It is also recognized that neither chemical fertilizers nor the organic manures alone can be used for sustainable crop production. Integration of inorganic and organic manures not only sustains crop production but is also effective in improving soil health and enhancing nutrient-use efficiency (Verma *et al.,* 2005). When sustainability of the crop and soil productivity is the burning issue, the integrated use of organics and inorganics needs to be emphasized. Several workers reported that incorporation of organic manures have been found to be the best means of restoring the soil fertility (Kumaraswamy, 1996; Yadav *et al*., 2013). However, use of organic manures alone cannot meet the huge nutrient requirement of rice crop (Yadwinder Singh *et al*., 1991). Hence, it is imperative to go for balanced fertilization through integrated nutrient management involving both organics and inorganics. The study area belongs to hill zone of Karnataka, therefore availability of different organic manures (FYM and vermicompost) and greenleaf-manuring crops, viz. gliricidia or quick stick [*Gliricidia sepium* (Jacq.) Steud.], eupatorium, sunhemp (*Crotalaria juncea* L.) are more.

In view of this as an alternative, inclusion of organic manures along with chemical fertilizers is only possible way. Therefore, in designing INM practices for improved long-term sustainability, continued research and grower

[1]**Corresponding author's Email:** manjappasirsi@gmail.com
[1]Dean (Horticulture), College of Horticulture, Hiriyur, Karnataka

experimentation are needed to optimize regionally relevant combinations of organic and inorganic sources. The present investigation was carried out to know the long-term effect of integrated nutrient management on productivity of rice and soil health.

MATERIALS AND METHODS

An experiment was conducted on fixed site at Agricultural Research Station (Paddy), University of Agricultural Sciences, Sirsi, Karnataka, India, during the rainy (*kharif*) seasons of 2000 to 2017 (18 years), to study the long-term effect of integrated nutrient-management practices on productivity and economics of rainfed lowland transplanted rice. The experimental site is situated in the hill zone (Zone - 9) of Karnataka which is located between 14º 37' 12.06" N and 74º 50' 60.09" E. The 18 years average annual rainfall (2000 to 2017) was 2,142 mm, the highest maximum temperature was 35.3ºC during April and minimum temperature was 14.0ºC during January.

The experiment was laid out in split-plot design with 7 main treatments, viz. M_1, no manure; M_2, FYM @ 10 t/ha; M_3, vermicompost @ 5 t/ha; M_4, eupatorium @ 10 t/ha; M_5, gliricidia @ 10 t/ha; M_6, sunhemp grown *in-situ* @ 8.96 t/ha; M_7, paddy straw @ 5 t/ha), and 3 subtreatments, viz. F_0, no fertilizer; F_1, 50% recommended dose of fertilizer (RDF); and F_2, 100% RDF, and replicated thrice. The size of the gross plot was 4.8 m × 4.5 m and net plot was 4.4 m × 4.1 m. The nutrient compositions and C : N ratio of different organic manures and green-manure crops are presented in the Table 1.

The organic manures were incorporated every year into the soil 2 weeks before planting as per the treatments. A long-duration (155 days) rice variety 'Abilash' was used in the experiment during all the years of experimentation. For planting, 30 days aged seedlings were used, and 2 to 3 seedlings were planted at each hill during the *kharif* season of every year. The fertilizers were applied in accordance with the treatments. Recommended dose of fertilizer, i.e. 75 kg N, 75 kg P_2O_5 and 87.5 kg K_2O/ha was used. The 50% each of N and K_2O and entire dose of P_2O_5 were applied at the time of planting. Remaining 50% of N and K_2O were given in 2 equal split doses–as top-dressing at 25 and 50 days after transplanting (DAT).

Observations on grain and straw yield were made at the time of harvesting of crop each year and economics was worked out based on the prevailed market prices of both input and output during each year of experimentation. Before the start of the experiment, initial composite soil sample was collected, processed and analysed for organic carbon and available major (N, P and K), secondary (Ca, Mg and S) and micro (Zn, Cu, Mn and Fe) nutrients. At the end of 18th year, the soil samples were collected from individual treatments after harvesting of the crop and were analysed for organic carbon and available major, secondary and micronutrients. The data pertaining to range of grain yield, straw yield and economics observed in 18 years of experimentation are presented and only pooled data (average of 18 years) and final data of soil chemical properties were analysed statistically as per the split-plot design under M-STAT-C programme.

RESULTS AND DISCUSSION

Grain and straw yield of rice

The results indicated that among the different organic manures, the grain and straw yields of rice were more with green-leaf manures, viz. gliricidia, eupatorium and sunnhemp, followed by FYM in most of the years of experimentation (Table 2). The average of 18 years pooled data showed that, application of gliricidia (@ 10 t/ha has recorded significantly higher grain (5.64 t/ha) and straw (6.94 t/ha) yields which were found at par with that of eupatorium @ 10 t/ha. The next best treatment in terms of both grain (5.37 t/ha) and straw yield (6.58 t/ha) was sunhemp and was found to be on a par with that FYM. Significantly lowest grain yield (4.57 t/ha) and straw yield (5.12 t/ha) were recorded in no-manure treatment. The range of grain yield (4.69–6.62 t/ha) and straw yield (5.8–8.1 t/ha) recorded during 18 years period was also maximum in gliricidia treatment followed by eupatorium treatment. Application of green manures might have better supply of macro and micro nutrients which might have helped for more enzymatic activities and physiological process of plant, which resulted in better translocation of photosynthates and portioning of dry matter to sink (Harish *et al.*, 2011; Manjhi *et al*., 2016). Among the inorganic fertilizer levels, an application of 100% RDF resulted in the highest

Table 1. Average nutrient content of manures/green-manures used in the experiment

Manure /green-manure corps	N (%)	P (%)	K (%)	C : N ratio
Farmyard manure	1.29	0.43	0.31	24.9
Vermicompost	2.13	0.93	0.44	26.6
Sunnhemp	2.52	0.30	2.20	12.3
Gliricidia	3.13	0.23	2.18	11.3
Eupatorium	2.22	0.21	2.34	13.1
Paddy straw	0.65	0.12	0.30	79.6

Table 2. Effect of organic manures and inorganic fertilizer levels on grain and straw yields of rainfed transplanted rice

Treatment	Grain yield (t/ha)		Straw yield (t/ha)	
	Range	Average of 18 years	Range	Average of 18 years
Organic manures (M)				
M_1, No-manure	3.96–5.59	4.57	4.57–6.28	5.12
M_2, FYM (10 t/ha)	4.49–6.22	5.36	5.45–7.42	6.29
M_3, Vermicompost (5 t/ha)	4.15–5.96	5.08	5.44–6.81	5.86
M_4, *Eupatorium* (10 t/ha)	4.53–6.41	5.56	5.71–8.06	6.75
M_5, *Gliricidia* (10 t/ha)	4.69–6.62	5.64	5.80–8.13	6.94
M_6, Sunnhemp (sown at 25 kg/ha)	4.54–6.10	5.37	5.05–8.15	6.58
M_7, Paddy straw (5 t/ha)	4.21–5.89	5.05	4.96–6.61	5.63
SEm±	–	0.51	–	0.87
CD (P=0.05)	–	1.41	–	2.41
Inorganic fertilizer levels (F)				
F_0, No-fertilizer	3.79–5.07	4.50	4.23–5.62	5.05
F_1, 50% RDF	4.5–6.02	5.28	5.46–7.33	6.15
F_2, 100% RDF	5.02–7.98	5.92	6.23–8.91	7.29
SEm±	–	0.29	–	0.47
CD (P=0.05)	–	0.80	–	1.30
Interactions of M × F				
$M_1 \times F_0$	3.11–4.73	3.73	3.53–4.77	4.05
$M_1 \times F_1$	3.96–5.57	4.67	4.69–6.38	5.10
$M_1 \times F_2$	4.63–6.49	5.30	6.03–8.08	6.20
$M_2 \times F_0$	3.86–5.03	4.46	4.07–5.58	4.81
$M_2 \times F_1$	4.48–6.54	5.53	5.58–8.11	6.42
$M_2 \times F_2$	5.11–7.21	6.10	6.70–8.71	7.64
$M_3 \times F_0$	3.48–4.82	4.18	3.78–5.94	4.54
$M_3 \times F_1$	4.20–6.04	5.25	5.52–7.43	5.93
$M_3 \times F_2$	4.75–7.02	5.81	5.91–8.71	7.11
$M_4 \times F_0$	4.13–5.76	5.09	5.05–6.81	5.87
$M_4 \times F_1$	4.49–6.24	5.42	5.34–8.02	6.60
$M_4 \times F_2$	4.76–7.22	6.18	6.67–9.47	7.78
$M_5 \times F_0$	4.14–6.18	5.17	5.15–7.10	6.04
$M_5 \times F_1$	4.76–6.50	5.52	6.11–7.63	6.89
$M_5 \times F_2$	4.97–7.20	6.24	6.14–8.67	7.88
$M_6 \times F_0$	3.87–5.60	4.56	3.85–5.89	5.47
$M_6 \times F_1$	4.60–5.87	5.40	5.31–7.78	6.52
$M_6 \times F_2$	4.99–6.85	6.16	5.99–9.92	7.74
$M_7 \times F_0$	3.52–5.10	4.33	3.82–5.50	4.59
$M_7 \times F_1$	4.36–5.95	5.14	4.80–6.21	5.61
$M_7 \times F_2$	4.77–6.76	5.67	5.77–8.11	6.70
SEm±	–	0.78	–	1.25
CD (P=0.05)	–	2.15	–	3.46

RDF, Recommended dose of fertilizer

grain (5.92 t/ha) and straw yield (7.29 t/ha) and was found significantly higher that of 50% RDF and no-fertilizer treatments.

Among the interactions of different organic manures and inorganic fertilizers, the combination of gliricidia @ 10 t/ha + 100% RDF resulted in significantly higher grain yield (6.24 t/ha) followed by eupatoium @ 10 t/ha + 100% RDF (6.18 t/ha), sunhemp grown *in-situ* @ 8.96 t/ha + 100% RDF (6.16 t/ha) and FYM @ 10 t/ha + 100% RDF (6.10 t/ha) which were found at par with each other (Table 2). The grain yield obtained with the combination of gliricida @ 10 t/ha + no-fertilizer (5.17 t/ha) and eupatorium @ 10 t/ha + no-fertilizer (5.09 t/ha) was found be on a par with that of no-manure + 100% RDF (5.30 t/ha) combination but significantly superior to that of no-manure + 50% RDF (4.67 t/ha). This indicates that, continuous application of green-leaf manures, viz. gliricidia or eupatorium @ 10 t/ha can give yield equivalent of 100% inorganic fertilizer. However, the grain yield obtained with the other manures, viz. sunhemp grown *in-situ* @ 8.96 t/ha + no fertilizer (4.33 t/ha), and FYM @ 10 t/ha + no fertilizer (4.46 t/ha) was found to be on a par with that of no-manure +

Table 3. Economics of rainfed transplanted rice as influenced by organic manures and inorganic fertilizer levels

Treatment	Gross returns (₹/ha)		Net returns (₹/ha)	
	Range	Average of 18 years	Range	Average of 18 years
Organic manures (M)				
M_1, No-manure	27,193–51,900	36,359	14,634–28,743	20,605
M_2, FYM (10 t/ha)	31,321–60,129	42,922	16,761–31,485	24,152
M_3, Vermicompost (5 t/ha)	29,881–55,468	40,628	15,827–27,822	22,123
M_4, *Eupatorium* (10 t/ha)	31,309–62,315	44,344	17,750–37,528	27,022
M_5, *Gliricidia* (10 t/ha)	32,992–61,593	45,057	19,433–36,806	27,724
M_6, Sunnhemp (sown at 25 kg/ha)	32,674–60,841	43,014	18,761–33,037	25,136
M_7, Paddy straw (5 t/ha)	30,819–58,616	40,225	16,760–29,317	21,916
SEm±	–	403	–	408
CD (P=0.05)	–	1,117	–	1131
Inorganic fertilizer levels (F)				
F_0, No-fertilizer	26,306–51,631	35,868	13,609–25,639	19,539
F_1, 50% RDF	31,257–59,468	42,301	17,505–32,046	24,695
F_2, 100% RDF	35,090–66,190	47,208	20,283–54,201	28,151
SEm±	–	228	–	646
CD (P=0.05)	–	632	–	646
Interactions of M × F				
$M_1 \times F_0$	21,533–41,329	29,328	10,029–19,394	14,945
$M_1 \times F_1$	27,139–55,098	37,571	14,580–31,320	21,824
$M_1 \times F_2$	32,908–61,272	42,173	19,294–37,850	25,046
$M_2 \times F_0$	26,370–51,976	35,364	12,866–25,888	17,967
$M_2 \times F_1$	30,325–63,071	44,258	15,766–34,495	25,484
$M_2 \times F_2$	37,268–66,192	49,144	21,654–37,055	29,006
$M_3 \times F_0$	22,995–47,208	33,084	13,120–19,991	16,083
$M_3 \times F_1$	31,971–58,087	41,767	17,925–29,702	23,395
$M_3 \times F_2$	34,678–63,604	47,034	19,564–34,587	26,891
$M_4 \times F_0$	29,115–56,682	40,616	16,611–32,542	24,654
$M_4 \times F_1$	30,303–60,933	43,700	16,744–36,146	26,368
$M_4 \times F_2$	34,508–70,434	48,717	19,894–43,897	30,044
$M_5 \times F_0$	28,942–58,279	71,405	16,438–33,072	25,443
$M_5 \times F_1$	34,352–60,003	44,493	20,973–35,216	27,160
$M_5 \times F_2$	35,501–69,809	79,272	20,887–43,272	30,569
$M_6 \times F_0$	25,161–54,846	37,032	12,467–29,445	20,471
$M_6 \times F_1$	34,206–62,600	43,516	20,266–34,708	25,672
$M_6 \times F_2$	36,065–66,446	48,495	21,105–38,794	29,265
$M_7 \times F_0$	25,151–51,189	34,247	12,307–23,382	17,212
$M_7 \times F_1$	29,966–58,392	40,803	15,907–28,835	22,695
$M_7 \times F_2$	34,699–66,268	45,625	19,585–36,437	25,839
SEm±	–	604	–	615
CD (P=0.05)	–	1,674	–	1,704

RDF, Recommended dose of fertilizer

50% RDF (4.67 t/ha), indicating 50% saving in inorganic fertilizer with continuous application of these manures. Similar trend was observed with respect to straw yield also. The beneficial effect of green-leaf manures may be because of their capacity to supply macro- and micro-nutrients in addition to their solubilizing effect on native soil nutrients due to the action of organic acids produced during decomposition (Pandey *et al.,* 2007; Tripathi *et al*., 2009). Similarly, Chaudhary *et al*. (2007) also reported the beneficial effect of integration of organic and inorganic fertilizer over inorganic fertilizer alone. The significantly lowest grain yield (3.73 t/ha) and straw yield (4.05 t/ha) were recorded with combination of no-manure and no-fertilizer ($M_1 \times F_1$) treatment.

Economics of rice

The pooled data on economics of rice as influenced by the application of organic manures indicated that, significantly higher net returns were realized with application of gliricidia @ 10 t/ha (₹27,724/ha) which was significantly superior to all other treatments except eupatorium @ 10 t/ha (₹27,022/ha) (Table 3). The net returns realized with

Table 4. Effect of organic manures and inorganic fertilizer levels on organic carbon and available nitrogen, phosphorus and potassium content of rainfed transplanted rice soils at the end of 18 years

Treatment	Organic carbon (%)	N (kg/ha)	P (kg/ha)	K (kg/ha)
Initial values (before start of experiment)	0.48	156	20.3	40.6
Organic manures (M)				
M_1, No-manure	0.62	139.6	22.7	38.9
M_2, FYM (10 t/ha)	0.74	177.5	31.0	46.6
M_3, Vermicompost (5 t/ha)	0.71	156.8	26.7	41.7
M_4, *Eupatorium* (10 t/ha)	0.75	177.3	26.9	48.8
M_5, *Gliricidia* (10 t/ha)	0.75	173.8	27.5	44.6
M_6, Sunnhemp (sown at 25 kg/ha)	0.73	171.4	30.2	44.8
M_7, Paddy straw (5 t/ha)	0.70	177.0	24.5	58.8
SEm±	0.029	7.23	1.29	4.67
CD (P=0.05)	0.091	22.30	2.97	14.30
Inorganic fertilizer levels (F)				
F_0, No-fertilizer	0.73	170.4	24.4	38.4
F_1, 50% RDF	0.69	170.7	27.5	45.9
F_2, 100% RDF	0.74	161.8	29.3	54.6
SEm±	0.016	8.28	0.97	2.97
CD (P=0.05)	0.046	NS	2.81	8.60
Interactions of M × F				
$M_1 \times F_0$	0.62	127.9	21.5	28.9
$M_1 \times F_1$	0.62	141.5	22.6	42.1
$M_1 \times F_2$	0.63	149.5	24.2	45.7
$M_2 \times F_0$	0.74	173.0	28.1	34.9
$M_2 \times F_1$	0.78	176.6	29.8	40.8
$M_2 \times F_2$	0.72	182.9	35.2	64.1
$M_3 \times F_0$	0.68	151.4	24.1	29.3
$M_3 \times F_1$	0.72	166.4	26.4	37.1
$M_3 \times F_2$	0.73	152.9	29.6	58.5
$M_4 \times F_0$	0.77	172.5	24.8	43.3
$M_4 \times F_1$	0.74	181.5	27.8	48.9
$M_4 \times F_2$	0.72	177.9	28.4	54.1
$M_5 \times F_0$	0.78	176.5	22.8	38.9
$M_5 \times F_1$	0.74	171.2	29.8	47.3
$M_5 \times F_2$	0.74	173.6	30.0	47.6
$M_6 \times F_0$	0.72	176.4	27.0	42.7
$M_6 \times F_1$	0.72	162.8	31.5	43.6
$M_6 \times F_2$	0.74	174.9	32.3	48.1
$M_7 \times F_0$	0.73	174.9	22.8	51.1
$M_7 \times F_1$	0.69	184.9	25.0	61.3
$M_7 \times F_2$	0.67	171.0	25.7	64.0
SEm±	0.04	21.90	2.56	7.86
CD (P=0.05)	0.11	60.44	7.07	21.69

RDF, Recommended dose of fertilizer

sunhemp grown *in-situ* @ 8.96 t/ha (₹25,136/ha) and FYM @ 10 t/ha (₹24,152/ha) were found at par with each other. Among the inorganic fertilizer levels, application of 100% RDF resulted in the highest net returns (₹28,151/ha) and was found significantly higher when compared to that of 50% RDF (₹24,692/ha) and no-fertilizer (₹19,539/ha) treatments.

Among the interactions of different organic manures and inorganic fertilizers, the combination of gliricidia @ 10 t/ha + 100% RDF has recorded significantly higher net returns (₹30,569/ha) followed by eupatoium @ 10 t/ha + 100% RDF (₹30,044/ha), sunhemp grown *in-situ* @ 8.96 t/ha + 100% RDF (₹29,265/ha) and FYM @ 10 t/ha + 100% RDF (₹29,006/ha) which were found at par with each other (Table 3). The net returns obtained with no-manure + 100% RDF (₹25,046/ha) were at par with application of either gliricidia (₹25,443/ha) or eupatorium (₹24,654/ha) @ 10 t/ha without any inorganic fertilizer.

Our results confirm the findings of Ramesh *et al.* (2009).

Soil-nutrient content

In general, there was significant improvement in soil-nutrient content with the application of manures as compared to that of no-manure treatment or initial values. Among the different organic manures, application of gliricida and eupatorium green-leaf manures exhibited higher soil organic carbon, available macro, secondary and micro- nutrients as compared to the other organic manures (Tables 4 and 5). The effect of different inorganic fertilizer levels on nutrient content was significant only with respect to phosphorus, potassium, sulphur and copper whose content was maximum with 100% RDF followed by 50% RDF and no-fertilizer. The interaction effect of organic manures and inorganic fertilizer levels on organic carbon and other nutrient content of soil were significant. In general, the organic carbon and other nutrients content was found to

Table 5. Influence of organic manures and inorganic fertilizer levels on the secondary and micro- nutrient contents of rainfed transplanted rice soils at the end of 18 years of experimentation

Treatment	Secondary nutrients			Micronutrients			
	Ca (ppm)	Mg (ppm)	S (kg/ha)	Zn (ppm)	Cu (ppm)	Mn (ppm)	Fe (ppm)
Initial values (before start of experiment)	325.5	58.9	22.1	1.70	1.45	7.10	103.50
Organic manures (M)							
M_1, No-manure	253.4	68.8	24.6	2.87	2.78	11.13	137.3
M_2, FYM (10 t/ha)	371.8	71.3	71.3	3.73	3.47	14.94	178.8
M_3, Vermicompost (5 t/ha)	384.7	69.1	69.1	3.31	3.26	11.57	155.6
M_4, *Eupatorium* (10 t/ha)	370.9	74.7	74.7	3.01	3.11	12.59	151.5
M_5, *Gliricidia* (10 t/ha)	368.3	80.5	80.5	2.60	3.14	13.90	161.5
M_6, Sunnhemp (sown at 25 kg/ha)	354.4	79.1	79.1	3.08	2.83	12.65	157.7
M_7, Paddy straw (5 t/ha)	372.5	89.9	89.9	3.62	2.88	13.47	174.6
M_7, Paddy straw (5 t/ha)	19.89	7.53	2.39	0.18	0.23	1.91	12.36
SEm±	62.26	NS	7.48	0.55	NS	NS	NS
CD (P=0.05)							
Inorganic fertilizer levels (F)	362.0	70.6	24.2	3.30	3.10	13.06	155.6
F_0, No-fertilizer	359.2	76.2	27.8	3.12	2.79	12.98	160.2
F_1, 50% RDF	382.8	81.7	30.6	3.11	3.31	12.66	162.9
F_2, 100% RDF	11.97	4.53	1.55	0.14	0.11	0.82	7.50
SEm±	NS	NS	4.48	NS	0.32	NS	NS
CD (P=0.05)							
Interactions of M × F	338.4	57.9	24.4	2.282	2.53	13.82	126.6
$M_1 \times F_0$	357.2	67.6	24.8	2.91	2.78	11.15	131.6
$M_1 \times F_1$	364.6	80.6	24.6	2.89	3.01	8.42	153.8
$M_1 \times F_2$	376.7	73.2	21.5	3.72	3.43	14.27	158.4
$M_2 \times F_0$	360.4	76.7	32.9	3.94	3.15	16.97	198.7
$M_2 \times F_1$	378.3	63.9	30.7	3.53	3.81	13.57	179.3
$M_2 \times F_2$	369.8	66.6	28.0	3.04	2.91	12.10	145.5
$M_3 \times F_0$	351.8	70.7	21.5	3.17	3.09	10.99	145.3
$M_3 \times F_1$	432.4	70.0	30.9	3.72	3.77	11.63	176.0
$M_3 \times F_2$	344.8	69.1	20.6	3.19	3.26	11.70	143.1
$M_4 \times F_0$	399.1	76.2	35.8	2.79	2.98	12.68	159.6
$M_4 \times F_1$	368.9	78.7	36.1	3.06	3.11	13.39	152.0
$M_4 \times F_2$	366.3	76.6	27.0	2.85	3.41	10.67	159.7
$M_5 \times F_0$	346.6	84.0	29.0	2.94	2.70	14.09	165.8
$M_5 \times F_1$	392.0	81.0	34.1	2.99	3.30	16.96	158.9
$M_5 \times F_2$	336.9	72.2	21.1	3.31	2.56	13.89	178.4
$M_6 \times F_0$	341.8	77.3	23.7	3.00	2.62	12.55	141.5
$M_6 \times F_1$	384.6	87.9	30.4	2.94	3.33	11.51	153.3
$M_6 \times F_2$	401.1	78.9	27.0	4.19	3.63	14.95	177.8
$M_7 \times F_0$	357.6	81.0	27.1	3.05	2.18	12.37	179.0
$M_7 \times F_1$	358.7	109.7	27.2	3.62	2.84	13.08	167.0
$M_7 \times F_2$	31.19	11.99	4.10	0.37	0.31	2.18	19.85
SEm±	86.08	33.09	11.32	1.02	0.86	6.02	54.79

RDF, Recommended dose of fertilizer

improve in combinations wherever organic manures were combined with inorganic fertilizer levels as compared to combinations of no-manure with inorganic fertilizer levels. The results are in conformity with those of Patel *et al*. (2013), who reported that all the treatments having integration of organics with inorganics showed the build-up of organic carbon as compared to the initial organic carbon values.

On the basis of the present findings, it can be concluded that the continuous application of green-leaf manures, viz. gliricidia or eupatorium @ 10 t/ha, found to give equivalent yield and net returns that would be obtained with 100% RDF. The other manures, viz. sunhemp and FYM, could give yield and returns equivalent to that of 50% RDF. The yield and net returns of rice increased further when organic manures were combined with inorganic fertilizers. The combination of gliricidia @ 10 t/ha + 100% RDF gave the maximum yield and net returns.

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