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Productivity and Profitability of Diversified Legume-based Cropping Systems in the Indo-gangetic Plains of India as Influenced by Nutrient Management

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ABSTRACT

Background: The continuing adoption of the rice-wheat cropping system (RWCS) and indiscriminate use of inorganic fertiliser has led to a decrease in soil fertility, an increase in multiple micronutrient deficiencies, a decrease in the water table and excessive greenhouse gas emissions, especially in the Indo Gangetic Plains. Adoption of crop diversification strategies, including legumes in cropping systems with integrated use of organic and inorganic nutrient sources, could be a viable option for achieving higher fodder tonnage and sustainable crop production in aforesaid ecologies.

Methods: A field experiment was conducted during the *kharif*, *rabi* and summer seasons of 2018-19 and 2019-20 in a split-plot design comprising four cropping systems (CS) *i.e.*, rice-wheat, rice-berseem, pearl millet-oats-moong bean and maize-cowpea-wheat in main plots; and four nutrient management (NM) practices *i.e.*, 100% RDF (recommended dose of fertiliser), 100% RDF + cow urine (foliar spray), 100% RDF + PGPR (seed treatments) and 75% RDF + cow urine + PGPR were assigned in sub-plots with three replications of each treatment.

Result: Investigations revealed that the significantly highest system productivity, net returns and higher nutrient availability were obtained under the rice-berseem cropping system with 100% RDF + PGPR treatment. The magnitude of increment in system productivity of the rice–berseem cropping system was 35.06, 57.87 and 87.29% over rice-wheat, maize-cowpea-wheat and pearl millet-oats-moong bean cropping system, respectively. The legume-based cropping system has strengthened and sustained crop productivity and profitability. The results of the present work confirmed that the adoption of legume-based crop diversification has significantly alleviated the crop yield of dairy-based farming systems.

Key words: Crop diversification, Legumes Nutrient Management, Profitability.

INTRODUCTION

India's population will reach 1.7 billion by 2050 and about 400 MT of food grain will be required to fulfil the demand (Anonymous, 2015). Similarly, India has the highest number of livestock (536.76 million) in the world (Anonymous, 2020). At present, India faces a net deficit of 35.6% green fodder and 10.95% dry fodder (Kumar *et al.,* 2023 and Ram *et al.,* 2022). Quality fodder deficiency reduces animals' productivity, which ultimately influences earnings from the livestock sector. The ever-increasing cereals and cash crops cultivation leads to shrinking the land for fodder cultivation which is the major constraint in improving green fodders production.

Rice-wheat cropping system (RWCS) is the most important cropping system in the world, covering an area of 26 million hectares (M ha) and immensely contributes towards food security, employment and income generation opportunities for rural masses not only in India but the entire Indo-Gangetic Plains (IGP) region (Banjara *et al.,* 2022). The continuing adoption of RWCS as well as dependence on and indiscriminate use of inorganic fertiliser for nutrient supply (Kumar *et al.,* 2022) has led to a decrease in soil fertility, an increase of multiple micronutrient deficiency, a decrease in the water table and excessive greenhouse gas emissions, especially in the Indo Gangetic Plains (Kumar *et al.,* 2021).

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To stabilize productivity, the diversification within RWCS is becoming essential and it will help to safeguard long-term soil fertility, crop productivity and profitability in India and attenuate the gap between current yields and yield potential (Shahane and Shivay 2019; Saha *et al.,* 2020). Crop diversification shows a lot of opportunities to fulfil basic needs and regulate farm income, control price fluctuation, withstand weather aberrations, conserve natural resources, ensure a balanced food supply, reduce the chemical fertilizer and pesticide loads, environmental safety and create employment opportunities (Gill and Ahlawat, 2006). Similarly, the inclusion of legumes in existing cropping systems through fodder crops in favour of a farming system approach will help indirectly to encourage farmers to grow fodder crops to promote the livestock sector and sustainable crop production. Legume crops also improved soil physical, biological and chemical properties through biological nitrogen fixation with symbiotic association with rhizobium from the atmosphere (Mallikarjun *et al.,* 2022). Nutrient management is an important aspect of achieving sustainable crop production. Judicious use of organic and inorganic sources of nutrients may sustain and enhance the productivity of food and fodder crops.

Therefore, keeping the above facts in view, a field experiment was conducted to find more productive and remunerative cropping systems to meet the requirements of food and fodder for the ever-increasing population of humans and livestock, respectively.

MATERIALS AND METHODS

A field experiment was conducted during *kharif*, *rabi* and summer seasons of 2018-19 to 2019-20 at ICAR-National Dairy Research Institute, Karnal, Haryana, located at 29°68' N latitude, 76°99' E longitude and an altitude of 257 m above mean sea level (AMSL). The climate of the study area is semi-arid, with a mean annual rainfall of 650 mm, out of which 70-80% is received during monsoon season. The total rainfall received during the cropping period was 926.80 mm in 2018-19 and 712.20 mm in 2019-20. The soil of experimental site was sandy clay loam in texture with neutral in reaction (pH 7.45, Jackson 1967), low in organic carbon (0.46%, Walkley and Black's 1934) and available nitrogen (212.33 kg/ha, Subbiah and Asija 1956), medium in available phosphorus (16.70 kg/ha, Olsen *et al.,* 1954) and potassium (255.43 kg/ha, Jackson 1967).

The experiment comprising of four cropping system (CS) *i.e.*, rice (*Oryza sativa* L.)- wheat (*Triticum aestivum* L.), rice - berseem (*Trifolium alexandrinum* L.), pearl millet (*Pennisetum glaucum* (L.) R. Br.) - oats (*Avena sativa* L.) - moong bean (*Vigna radiata* L.) and maize (*Zea mays* L.) - cowpea (*Vigna unguiculata* L.) - wheat in main plots and four nutrient management (NM) practices *i.e.*, N1: 100% RDF, N2: 100% RDF + cow urine (foliar spray), N3: 100% RDF + PGPR (seed treatments) and N4: 75% RDF + Cow urine + PGPR were assigned in sub-plots in split plot design with three replications. The crop varieties were used as PB-1121 (Rice), Nutri-feed (Pearl millet) and African Tall (Maize) during *Kharif*; HD-2967 (Wheat), BL-42 (Berseem) and Kent (Oats) during *rabi*; MH-421 (Moong bean) during summer season and C-152 (Cowpea) during post-monsoon season.

All the crops were sown as line sowing except berseem (broadcasting) at recommended spacing (cm) *viz.*, rice at 20×15 cm (Transplanting); wheat at 22.5×5 cm; maize at 40×10 cm; pearl millet, oats, moong beanand cowpea at 30×10 cm. The recommended dose of N: P_2O_5: K_2O per hectare in rice (100:60:50 kg), wheat (120:50:40 kg), berseem (20:60:40 kg), pearl millet (80:30:30 kg), oats (100:40:40 kg), moong bean (20:50:30 kg), maize (100:40:40 kg) and cowpea (20:50:30 kg) was applied through urea, diammonium phosphate and muriate of potash as per the treatments, respectively. The full dose of fertiliser (N: P_2O_5: K_2O) was applied as basal in leguminous crops (berseem, moong bean and cowpea), while a full dose of P_2O_5 and K_2O along with a half dose of N were applied as basal and remaining N was applied in 2 splits in cereal crops (rice, wheat, pearl millet, oat, maize). In all the crops PGPR was used as seed treatment before 2 hours of sowing and cow urine as foliar spray (10%) at 30 and 45 DAS/DAT as per the treatment. All others package of practices was followed as per standards and recommendations for each crop. Harvesting was done at physiological maturity in rice, wheat, berseem (last cutting for seed production), oats and moong bean; at 50% flowering stage in pearl millet, maize and cowpea. In the case of berseem, the crop was left for seed production after three cuttings of fodder. The net plot area of the crop from each plot was manually harvested and fresh biomass yield was weighted, thereafter it was converted into tonnes/ha. In the case of grain or seed crops after threshing the grain/seed and straw/stover yield from each net plot area was weighted and converted into tonnes/ha.

To compare the performance of various cropping systems, the economic yield of each crop was converted into rice-equivalent yield (REY) based on minimum support and prevailed market price as per the procedure described by Lal *et al.* (2017).

$$\text{REY(t/ha)}: \frac{(\text{Yx}) \times (\text{Px})}{\text{Py}}$$

Where

REY: Rice-equivalent yield.

Yx: Yield (t/ha) of x crop (economic harvest).

Px: The price of x crop (`/quintal).

Py: The price of rice (`/quintal).

The economics was calculated based on prevailing market prices of different inputs and outputs. System yield and economics were calculated based on, the addition of all economic components of each crop within each cropping system. All data recorded were statistically analysed with the help of analysis of variance (Gomez and Gomez 1984). Significance among treatments means differences for various parameters were analysed by least significant differences (LSD) at 0.05 probability level.

RESULTS AND DISCUSSION

Crop yields

The rice grown under the rice-wheat and rice-berseem cropping system was not affected significantly by grain and straw yields (Table 1). Similarly, wheat grain and straw yield were also not affected significantly by rice-wheat and maize-cowpea-wheat cropping systems. However, numerically higher grain (57.19 q/ha) and straw (85.87 q/ha) yields were recorded in the maize-cowpea-wheat cropping system. Yield of individual crops was significantly affected by different nutrient management practices (Table 1) and significantly higher grain (44.83 q/ha) and straw (88.73 q/ha) yields of rice were obtained with application of 100% RDF + PGPR, which was statistically at par with 100% RDF + CU, 75% RDF + PGPR + CU. Similarly, grain (58.80 q/ha) and straw yields (88.41 q/ha) of wheat; green fodder (963.62 q/ha) and seed yields (2.15 q/ha) of berseem; green fodder yield (616.82 q/ha) of pearl millet; grain (33.34 q/ha) and straw yields (97.82 q/ha) of oats; grain (6.71 q/ha) and stover yields (36.70 q/ha) of moong bean; green fodder yield of maize (495.86 q/ha) and cowpea (228.51 q/ha) was recorded with 100% RDF + PGPR, which was found statistically on par with 100% RDF + CU, 75% RDF + PGPR + CU. The application of PGPR colonizes the root systems of plants and contributes to their growth and development. The beneficial bacteria produce plant growth hormones, fixing atmospheric N, solubilizing and mobilizing the native soil P and K and also regulating hormonal by releasing certain organic acids like gluconic, lactic, citric, tartaric, resulting in enhanced nutrient uptake, improved crop yield and resilience and minimizes nutrient losses to the environment (Yadav *et al.,* 2022). Application of PGPR improves nutrient uptake by altering the level of plant hormone that enhances root surface area by increasing its girth and shape, thereby helping in absorbing more nutrients in plants leading to increased crop yield (Mohanty *et al.,* 2021).

Rice equivalent yield

The rice equivalent yield of individual crops was not affected significantly by the cropping systems. However, the system productivity of diversified cropping systems was significantly affected by various cropping systems (Table 2). Among different cropping systems, significantly higher system rice equivalent yield was recorded in the rice-berseem (113.67 q/ha) followed by rice-wheat (84.16 q/ha), maize-cowpea-wheat (72.00 q/ha) and pearl millet-oats-moong bean (60.69 q/ha) cropping system. The significantly highest system productivity was recorded in order of rice–berseem > rice–wheat > maize–cowpea–wheat > pearl millet–oats-moong bean cropping system. The magnitude of increment in system productivity of the rice–berseem cropping system was 35.06, 57.87 and 87.29% over rice–wheat, maize–cowpea–wheat and pearl millet–oats-moong bean cropping system, respectively. Among different nutrient management practices, rice equivalent yield of individual crops and system productivity were significantly affected by various nutrient management practices (Table 2). The significantly higher rice equivalent yield of wheat (41.74 q/ha), berseem (70.42 q/ha), pearl millet (26.44 q/ha), oats (21.78 q/ha), moong bean (15.19 q/ha), maize (21.25 q/ha) and

Table 1: Effect of cropping systems and nutrient management practices on yields (q/ha) (Mean of two years).

Treatments	Rice yield		Wheat yield		Berseem yield		Pearl millet	Oats yield		Mung yield		Maize green	Cowpea
	Grain	Straw	Grain	Straw	Green fodder	Seed	green fodder	Grain	Straw	Grain	Stover	fodder	green fodder
Cropping Systems													
R-W	42.25	83.97	55.68	83.60	-	-	-	-	-	-	-	-	-
R-B	43.98	86.67	-	-	929.77	1.97	-	-	-	-	-	-	-
P-O-Mu	-	-	-	-	-	-	597.98	31.89	94.40	6.25	34.77	-	-
M-C-W	-	-	57.19	85.87	-	-	-	-	-	-	-	476.98	219.48
SEm±	0.84	1.66	0.66	0.99	-	-	-	-	-	-	-	-	-
CD (P=0.05)	NS	NS	NS	NS	-	-	-	-	-	-	-	-	-
Nutrient Management													
N1	41.66	82.41	54.85	82.47	898.77	1.83	578.55	30.69	91.69	6.00	33.60	462.90	212.56
N2	42.81	84.72	56.04	83.81	927.83	1.94	596.93	31.74	93.96	6.13	34.32	474.39	218.32
N3	44.83	88.73	58.80	88.41	963.62	2.15	616.82	33.34	97.82	6.71	36.70	495.86	228.51
N4	43.17	85.42	56.04	84.26	928.87	1.97	599.61	31.79	94.13	6.17	34.47	474.76	218.55
SEm±	0.67	1.33	0.90	1.35	10.48	0.07	6.55	0.48	1.13	0.18	0.78	6.31	3.01
CD (P=0.05)	2.06	4.10	2.77	4.17	36.26	0.23	22.66	1.65	3.92	0.63	2.68	21.83	10.42

Table 2: Rice equivalent yield and system productivity (q/ha) of various cropping systems (Mean of two years).

Treatments	Rice	Wheat	Berseem (Green fodder +seed)	Pearl millet green fodder	Oats	Mung	Maize green fodder	Cowpea green fodder	System productivity
Cropping systems									
R-W	44.65	39.51	-	-	-	-	-	-	84.16
R-B	46.46	-	67.21	-	-	-	-	-	113.67
P-O-Mu	-	-	-	25.63	20.88	14.18			60.69
M-C-W	-	40.58	-	-	-	-	20.44	10.97	72.00
SEm±	0.89	0.47	-	-	-	-	-	-	0.36
CD (P=0.05)	NS	NS	-	-	-	-	-	-	1.25
Nutrient Management practices									
N1	44.01	38.93	64.41	24.79	20.14	13.61	19.84	10.63	79.83
N2	45.23	39.73	66.84	25.58	20.79	13.91	20.33	10.92	82.07
N3	47.36	41.74	70.42	26.44	21.78	15.19	21.25	11.43	86.17
N4	45.61	39.78	67.16	25.70	20.82	13.99	20.35	10.93	82.43
SEm±	0.71	0.64	1.07	0.28	0.30	0.40	0.27	0.15	0.48
CD (P=0.05)	2.18	1.97	3.71	0.97	1.02	1.39	0.94	0.52	1.4

Table 3: Effect of cropping system and nutrient management on available nutrients and physical properties of soil (Mean of two years).

Treatments	pH	EC(dS/m)	OC(%)	AvailableN (kg/ha)	AvailableP (kg/ha)	AvailableK (kg/ha)
Initial Values	7.95	0.35	0.53	195.40	16.60	191.60
Cropping system						
RW	7.98	0.37	0.52	183.56	16.06	189.35
RB	7.84	0.34	0.55	212.53	18.41	218.31
POMu	7.92	0.33	0.57	207.91	18.08	220.80
MCW	7.92	0.34	0.56	208.78	18.41	216.82
SEm±	0.03	0.01	0.01	3.83	0.16	4.28
CD(P=0.05)	NS	NS	0.03	13.26	0.54	14.82
Nutrient management						
N1	7.93	0.35	0.55	195.22	17.07	205.60
N2	7.94	0.33	0.54	198.03	17.57	207.89
N3	7.92	0.35	0.54	210.24	18.37	218.06
N4	7.88	0.34	0.57	209.30	17.95	213.73
SEm±	0.03	0.01	0.01	2.55	0.20	3.15
CD(P=0.05)	NS	NS	NS	7.43	0.57	9.19

cowpea (11.43 q/ha) were recorded under 100% RDF + PGPR, which was found statistically on par with 100% RDF + CU, 75% RDF + PGPR + CU treatment. Similarly, the rice equivalent yield of the system was significantly influenced by different cropping systems and nutrient management practices. Similarly, among various nutrient management practices, the significantly highest rice equivalent yield of the system was observed with 100% RDF + PGPR followed by 75% RDF + PGPR + CU and 100% RDF + CU treatment. The REY of an individual crop in the cropping system depends upon its yield achieved and selling price in comparison to the selling price of rice. Therefore, the rice equivalent yield differed in diverse cropping systems (Kumar *et al.,* 2021).

Soil fertility

The results revealed that soil pH and EC were not affected significantly by various cropping systems and nutrient management practices (Table 3). soil organic carbon (OC) was significantly affected by fodder-based cropping systems and the pearlmillet-Oat-Mungbean and Maize-cowpea-wheat cropping systems had recorded significantly higher organic carbon as compared to rice-based cropping systems. The available N, P and K were significantly affected by diversified cropping systems and nutrient management practices (Table 3). The significantly higher available N, P and K were observed with legume-based cropping systems (rice-berseem, Pearlmillet-Oat-Mungbean and Maize-cowpea-wheat) as compared to rice-wheat cropping system. Among nutrient management practices significantly higher available N, P and K have been observed with the combined application of plant growth-promoting rhizobacteria (PGPR) and fertilizers compared to the sole application of 100% fertilisers through

Table 4: Effect of diversified cropping systems and nutrient management practices on system economics (Mean of two years).

Treatments	System economics			
	Cost of cultivation (`/ha)	Gross returns(`/ha)	Net returns(`/ha)	Benefit: Cost ratio
Cropping systems				
RW	73420	294546	221126	3.01
RB	79741	397836	318094	3.99
POMu	60866	212402	151536	2.50
MCW	63710	251985	188275	2.96
SEm±	-	1262	1262	0.02
CD (P=0.05)	-	4369	4369	0.06
Nutrient management				
N1	67379	279394	212015	3.09
N2	72469	287248	214779	2.91
N3	67829	301611	233782	3.39
N4	70061	288516	218455	3.07
SEm±	-	1692	1692	0.02
CD (P=0.05)	-	4938	4938	0.07

chemical sources. The application of PGPR increased N by biological fixation, P by solubilizing fixed inorganic soil phosphate to available form and K by secretion of organic acid that increases the availability of these nutrients (Cakmakci *et al.,* 2007). These results were also in close conformity with the findings of Meena *et al.* (2023).

System economics

Among various cropping systems gross return, net return and B: C ratio of diverse cropping systems was significantly affected by various cropping systems (Table 4). In the system basis, the highest cost of cultivation recorded was recorded in the rice-berseem (79741 ` /ha) cropping system followed by rice-wheat (73420 ` /ha), maize-cowpea-wheat (63710 ` /ha) and lowest in pearl millet-oats-moong bean (60866 ` /ha) cropping system (Table 4). The highest cost of cultivation was observed in the rice-berseem cropping system due to a higher number of labourers engaged in transplanting and other cultural operations of rice and harvesting of green fodder of berseem. Also, both rice and berseem require a long duration in the field for maturity. The highest gross return (397836 ` /ha), net return (318094 `/ha) and B: C ratio (3.99) were recorded in the rice-berseem cropping system due to higher system yields and output selling prices of basmati rice and berseem seeds. Among different nutrient management practices in the system, the highest cost of cultivation (72469 `/ha) was recorded in 100% RDF + CU and the lowest (67379 `/ha) was recorded in 100% RDF treatment. Between the nutrient management practices highest gross return (301611 `/ha), net return (233782 `/ha) and B: C ratio (3.39) were recorded with 100% RDF + PGPR treatment. Saha *et al.* (2020) and Hindoriya *et al.* (2019) also found better economic returns by diversification of rice and integrating legumes based cropping system. Kumar *et al.,* 2021 observed in northwest Indo-Gangetic Plains, that the maize-potato-onion cropping systems improved gross return, net returns and B: C ratio as compared to the rice-wheat cropping system.

CONCLUSION

Thus, it is concluded that, rice-berseem cropping system proved the best among various cropping systems tested, particularly for system productivity, gross returns and net returns. Thus, it can recommended that, the rice-berseem cropping system can partially replace the existing rice-wheat cropping system that is observed by many as unsustainable and a cause of concern in numerous aspects to fulfil the green fodder requirement and ensure food security for dairy-based farming systems.

Conflict of interest

On behalf of all authors I stated that there was No conflict of interest to publish this manuscript.

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