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Scientific validation of indigenous organic formulation-*panchagavya* for sustaining rice productivity and residual effect in rice-lentil system under hot semi-arid eco-region of middle Indo-Gangetic plains

Pravin Kumar Upadhyay*[,1,+], Avijit Sen[2], Sanjay Singh Rathore[1] & Bipin Kumar[2], Ram Kumar Singh[2], Saroj Kumar Prasad[2], Ardith Sankar[2]

[1]ICAR-Indian Agricultural Research Institute, New Delhi 110 012, India

[2]Institute of Agricultural Sciences, Banaras Hindu University, Varanasi 221 005, India

E-mail: [+]pravin.ndu@gmail.com

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Combined application of organic source of nutrient and inorganic fertilizers increases nutrient synchrony and reduces losses leading to sustainable productivity. With this concept in mind a field trial was conducted at Varanasi, India during 2013–14 and 2014–15, to evaluate and validate the efficiency and efficacy of *panchagavya* (blend of five cow products i.e. dung, ghee, curd, urine and milk) in combination with recommended doses of fertilizers (RDF) on rice yield, soil microbial population, soil microbial biomass carbon (SMBC), soil enzymatic activity and their residual effects on lentil. Application of *panchagavya* (D_4-seedling root dip + one spray at 30 days after transplanting-DAT @ 6% + application through irrigation water at 60 DAT) produced higher productive tillers/m^2, number of filled spikelets/panicle, leaf area index (LAI), grain yield, soil bacterial and fungal population, SMBC and dehydrogenase activity. Application of 100% RDF significantly increased grain yield (5935 kg/ha) but 120% RDF recorded the highest straw yield (8283 kg/ha) and biological yield. Residual effect of *panchagavya* at D_4 level resulted in higher (19.1% over control) seed yield of lentil. However, conjunctive use of 100% RDF and D_4 ensured maximum net return (1194.9 $/ha).Therefore, use of indigenous product i.e. *panchagavya* in combination with fertilizer can be inferred to improve soil health, ascertain high productivity, profitability and sustainability in rice-lentil production, while preserving natural resource base under hot semi-arid eco-region of middle Indo-Gangetic Plains (IGP).

Keyword: Dehydrogenase, Microbial population, *Panchagavya*, Recommended Dose of Fertilizer, System of Rice Intensification

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Globally rice is grown in 163.2 Mha area out of which India accounts for about 43.57 Mha[1]. India ranks first in rice acreage, second in production (104.32 million tonnes/Mt) with a productivity of 2.38 t/ha[2]. The environmental implications of rice ecosystem, heavy use of agrochemicals and flooded conditions could lead to substantial water use and pollution[3-4], high dependence on energy[5], and considerable GHG emissions[6].

Application of inorganic fertilizers alone cannot sustain the soil fertility and productivity under various cropping sequences. Therefore, continuous use of high rates of fertilizers with poor use efficiency may lead to many undesirable environmental consequences[7-8]. Sustained realization of the potential yield of crops is possible through integrated nutrient sources by making the system more productive, profitable and healthy[9]. With high grain yield potential hybrid rice removes a substantial amount of major and minor nutrients from the soil in which deficiency of any essential nutrient may reduce the yield. It is also a fact that in rice puddled soil application of fertilizer leads to a huge loss of N (NUE being 30-50%, PUE being 15-20%) by several means like leaching, denitrification, volatilization, run off. The nutrient loss is having cascading effect in enhancing cost of production. The price of inorganic fertilizers is increasing; therefore emphasis is needed to maximize the nutrient-use efficiency, grain yield and minimize the cost of production. However, it is imperative to use indigenous technologies in integrated manner so that the potential yield of hybrid rice could be realized on sustained basis.

*Corresponding author

Indigenous Technical Knowledge (ITK) is vital for self-dependency and is based on nativity. This is drawn on local resources and is more resilient than the externally introduced practices which can be costly, scarce and irregular in availability[10]. Any practice, considered valid and fruitful should have a scientific basis for its successful results. Farmers are not able to explain the scientific rationale behind indigenous practices although they have their own world views attributed with informal knowledge; therefore, studies are required to test and verify those practices to find out their rationality. One such practice used by the farmers is *panchagavya*. It is an organic product has the potential to play the role of promoting growth and providing immunity in plant system. It consists of 8 products viz. cow dung, cow urine, milk, curd, jaggery, ghee, banana, and water. When suitably mixed and used, these have astonishing effects. *Panchagavya* has been produced and used by the farmers from ancient times. When it is applied as spray or through root dip increases quality parameters *viz.*, crude fiber, protein, ascorbic acid, carotene content and shelf life of rice[11], due to the presence of substantial quantities of IAA and GA_3 which act as stimuli for production of growth regulators in plant system[12] thereby enhancing the growth and yield of rice[13]. The key feature of *panchagavya* is its efficacy to restore the yield level of all crops during transitory period of organic culture from the very first year[14].

Thus they were using products like *panchagavya*, organic manures, green manures, etc. to boost the growth of plant. However, over the decades growth rate of agriculture has significantly decreased from 8.37 per cent in 1960-70 (era of green revolution) to 2.61 per cent during 2000-2010, which poses a challenge to produce enough food for increasing population. Though the food grain production in the recent years has crossed 270 Mt; India has to produce an additional 5-6 Mt of food grains annually in the next decade to meet the requirements of an estimated population of nearly 1.6 billion by 2050. According to the 29th report, called “Impact of chemical fertilizers and Pesticides on agriculture and allied sectors in the country-2014-15”, the reason for decreasing soil fertility in the country was identified to be unequal or imbalance use of fertilizers. The committee thus recommended for revision of the existing fertilizer subsidy policy and promotion of organic product like *panchagavya* or bio-fertilizers.

In this context, authors want to firmly emphasize the need to adopt eco-friendly agricultural practices for sustainable agriculture by combined application of recommended dose of fertilizers and organic formulations i.e. *panchagavya*. Because, incorporation of *panchagavya* along with inorganic fertilizer in system of rice intensification is important for reducing the cost of cultivation and pollution by improving fertilizer use efficiency. Complementary use of organic and biological sources of plant nutrient along with chemical fertilizer is of great significance for the maintenance of optimum soil health and high productivity. Keeping these facts in view, the investigation was carried out to study the stimulatory effect of an on-farm bovine products and by-products i.e. *panchagavya* on plant, soil and the fertilizer use efficiency (FUE) of rice.

Methodology

Study area

A field experiment was conducted at the Agricultural Research Farm of the Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India during 2013-14 and 2014-15 (25°15'19.7" N latitude, 82°59'34.2" E longitude, 75 ASL). The soils of the experimental field was sandy clay loam in texture, had bulk density 1405 kgm^{-3} and water holding capacity 40.54%, neutral in reaction (7.43), low in organic carbon (0.33%), low in available nitrogen (203 kg/ha) and medium in available phosphorus in the form of P_2O_5 (21.17 kg/ha), potassium in the form of K_2O (192.5) and low in zinc (0.38 ppm).

Meteorological conditions

Varanasi falls in the belt of semi-arid to sub-humid climate receiving a mean assured rainfall of > 1100 mm and potential evapotranspiration of about 1525 mm. Data on meteorological parameters were obtained from the meteorological observatory of the All India Coordinated Research Project on Dryland Agriculture, BHU, Varanasi. The mean weekly maximum temperature was observed in the range of 16.25-36.5 °C with an average of 27.8 °C. The weekly mean minimum temperature varied from 9.2 to 27.6 °C with an average of 19.11°C. The total rainfall received during the cropping period was 885.9 mm. The weekly mean sunshine duration varied from 0.8 to 8.8 hrs. The detail of weather parameters has been given in the Fig. 1.

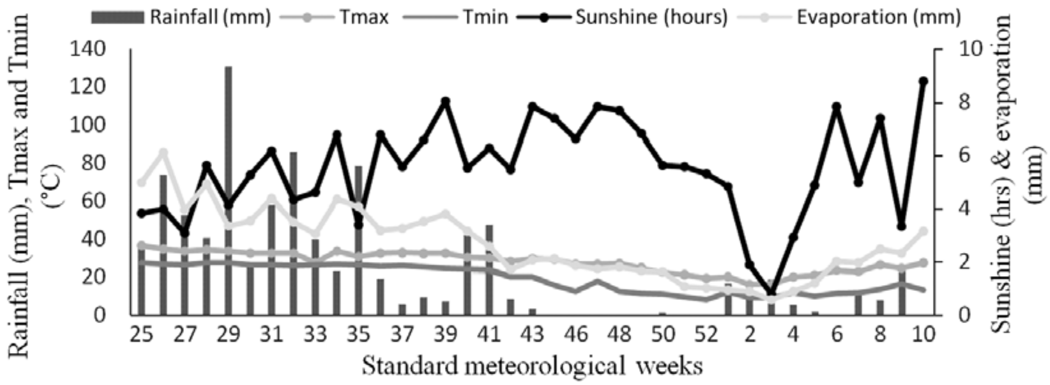

Fig. — 1 Meteorological observations of rice-lentil season (mean of two years)

Experimental design and layout

Considering the nature of factors under study and the convenience of agricultural operation, the experiment was laid out in a split-plot design with three replications. The fertilizer doses were assigned to main plots and *panchagavya* treatments in sub plots. PRH10 - a hybrid basmati cultivar was used having yield potential of 6500 kg/ha and mature in 110-115 days. Treatments consisted of fertilizers combinations in main plots (60% of RDF, 80% of RDF, 100% of RDF and 120% of RDF) and five *panchagavya* treatments (control, three sprays at 15, 30 and 45 DAT @ 3%, seedling dip + one spray at 30 DAT @ 3 % + application through irrigation water at 60 DAT, three sprays at 15, 30 and 45 DAT @ 6% and seedling dip + one spray at 30 DAT @ 6% + application through irrigation water at 60 DAT)

Nutrient application was done as per the predetermined levels. The recommended dose of fertilizer for rice crop was 150, 75, 75 and 5.25 kg/ha of N, P_2O_5, K_2O and Zn respectively. Fertilizers were calculated and applied to rice crop based on the treatment. One fourth dose of nitrogen and full dose of P, K and Zn were applied after last puddling and remaining three-fourth in two different splits, first two-fourth at tillering stage (30 days after transplanting) and second one-fourth at panicle initiation stage (55 days after transplanting).

Panchagavya

For preparing *panchagavya*[15], a wide mouthed plastic container was used as metal containers are not recommended to be used. First the fresh cow dung (12.5 kg) and cow's ghee (2.5 kg) were put into container and mixed it thoroughly for 3 days twice in a day. On the fourth day added the rest of the ingredients (cow urine-7.5 L, milk-7.5 L, curd 5 L, Jaggery-1.25 kg and banana-30 in number) and final volume 50 L was maintained by adding water. Stir it twice daily for 15 days. The *panchagavya* stock solution was ready after the 20th day. It was kept in the shade and covered with a plastic mosquito net to prevent houseflies from laying eggs and the formation of maggots (worms) in the solution. Whenever required suitable quantity of water was added to keep the slurry in a liquid state. The chemical and biological parameters were analyzed after 20 days of *panachagavya* preparation and found pH 5.92, EC 3.7 (dSm^{-1}), available N 3983 ppm, available P 2450 ppm, available K 1966 ppm, zinc 41.66 ppm, organic carbon 0.56%, bacteria $32.64x10^6$in number fungi107006 in number and actinomycetes18x10 in number

Management practices

Approximately 100 m^2 nursery area is required for transplanting one hectare land in case of system of rice intensification. Healthy seed of cultivar 'PRH 10' were selected and sown separately by spreading method of nursery bed @ 5 kg/ha. Raised nursery beds having a width of 1 m and length of 10 m with 40 cm channels all around were prepared for sowing of seed. The nursery beds were prepared with a massive mixture of soil and FYM at 2:1 ratio. Prior to sowing, seeds were treated with streptocycline and carbendazim (@ 6 g of streptocycline in 20 L of water and 1 g of carbendazim dissolved in one litre water. Prior to sowing seeds were soaked in water for 48 hours for quick and uniform germination and then allowed to dry in shade before broad casting in the nursery bed. Sprouted seeds @ 20 g/m were spread uniformly on moist soil such a manner that each seed could be isolated from other. The seed was covered on seed beds with wheat straw at least two days after sowing to protect them from birds and keep the soil moist. After covering the seed, watering was done with *hajara* twice (morning and evening) in a day. 14 days old seedlings @ 1 seedling per hill were transplanted at the spacing of 25 cm × 25 cm.

Statistical analysis

The observations recorded during the course of investigation were tabulated and analyzed statistically to draw a valid conclusion. SPSS 17.0 statistical software[16] was used for the standard analysis of variance (ANOVA) to compare the treatment means for each year separately. Treatment means were compared at the 5% level of significance ($p < 0.05$) using least significant difference. The variance over years was estimated homogeneously by performing Bartlett's x2 test and results of pooled analysis are presented here to draw logical inferences.

Results

Growth parameters of rice

The result revealed that (Table 1) the maximum height (99.25 cm), tillers/hill (13.8), dry matter accumulation (67.5 g/hill), leaf area index (4.6) and SPAD value (43.6) were recorded by the application of *panchagavya* (seedling root dip + one spray at 30 DAT (6%) + application through irrigation water at 60 DAT) followed by D_3 (three sprays at 15, 30 and 45 DAT @ 6%) which was remained at par with D_4 with respect of plant height (97.9 cm), tillers/hill (13.5), dry matter accumulation (65.6 g/hill) and LAI (4.5).

Application of 120% RDF produced significantly taller plants (102.38 cm), tillers/hill (15.3), dry matter accumulation (68.6 g/hill), leaf area index (4.9) and SPAD value (45.4) as compared to 60, 80 and 100% RDF. 100% RDF was at par with respect of plant height (97 cm) over 120% RDF. 60% RDF i.e. 90 kg N, 45 kg P_2O_5, 45 kg K_2O and 15 kg zinc sulfate recorded lowest plant height, tillers/hill, dry matter accumulation, SPAD, LAI and days to 50% flowering.

Yield attributes

Yield attributes were influenced by *panchagavya* and RDF levels (Table 1). *S*ignificant improvement in productive tillers/m^2 (215.6) and number of filled spikelets/panicle(147.2) and less sterility (12.5%) were observed with the D_4 level of *panchagayva* treatments while 100% RDF produced higher effective tillers/m^2 (221.3) and number of filled spikelets/panicle (151.2) and lesser sterility percentage (11.7).

Yield

100% RDF produced 5935 kg/ha of yield and D_4 treatment of *panchagavya* produced 5896 kg/ha of yield. But, interactive effects of these two treatments were more prominent in producing higher yield of 6334 kg/ha (Fig. 2) of rice.

Interactive response of *panchagavya* with RDF on grain yield of rice has been given in Fig. 2 and based on the best combination i.e. F_3D_4 a response line (Fig. 3) was drawn which showed the quadratic function. In the present investigation there was a positive response to the successive increasing dose of RDF up to 100% and level of *panchagavya* up to

Table 1 — Effect of fertilizer dose and time and rate of *panchagavya* application on SPAD, LAI and yield attributes of rice

Treatment	Plant height (cm)	No. of tiller/hill	Dry weight (g)	SPAD	LAI (60 DAT)	Productive tillers/m^2	No. of filled spikelet/panicle	Sterility (%)
A. Fertilizer dose								
F_1	86.9^c	10.2^d	58.1^d	38.0^c	3.7^c	161.9^d	131.8^c	15.0^a
F_2	92.6^b	11.5^c	61.1^c	40.4^b	4.1^b	184.0^c	135.3^c	14.1^b
F_3	97.0^a	14.0^b	64.2^b	42.3^b	4.5^b	221.3^b	151.2^a	11.7^d
F_4	102.4^a	15.3^a	68.6^a	45.4^a	4.9^{ba}	203.9^a	144.3^b	13.0^c
B. Panchagavya application								
D_{0D} D_0	84.5^c	10.8^b	56.5^c	37.4^c	3.7^c	154.3^d	131.6^c	14.6^a
D_1	95.2^b	12.8^a	61.8^b	41.8^b	4.3^b	191.1^c	139.2^b	13.7^b
D_2	96.5^b	13.0^a	63.5^b	42.3^b	4.4^b	196.5^c	141.2^b	13.4^b
D_3	97.9^{ab}	13.5^a	65.6^{ab}	42.5^b	4.5^{ab}	206.2^b	144.2^{ab}	13.0^b
D_4	99.5^a	13.8^a	67.5^a	43.6^a	4.6^a	215.6^a	147.2^a	12.5^c

F1, F2, F3 and F4 are the 60, 80, 100 and 120% RDF respectively, D0-Control, D1-Three sprays at 15, 30 and 45 DAT @ 3%, D2-Seedling root dip + one spray at 30 DAT @ 3% + application, through irrigation water at 60 DAT, D3-Three sprays at 15, 30 and 45 DAT @ 6%, D4-Seedling root dip + one spray at 30 DAT @ 6% + application through irrigation water at 60 DAT

Note1. Within column, value represents with different letter indicate significant difference (P=0.05)
Note 2. Value in tables are mean of two year study

D_4 level beyond which a declining trend was observed. The optimum economic fertilizer dose calculated for best production was 107.3 kg N, 53.7 kg P_2O_5 and K_2O and 3.8 kg Zn/ha in association with D_4*panchagavya* package. Soil quality parameters *viz.* microbial population, biomass carbon and enzymatic activities were highly improved by D_4 package of *panchagavya* which in turn made the nutrients more available in soil resulting in enhanced uptake and more efficient assimilation. This was most probably the reason behind the better yield of crop obtained at F_3D_4 treatment.

Soil microbial population

Among the *panchagavya* treatments, D_4 recorded significantly higher (Table 3) bacterial population (54.8 at 30 DAT, 79.8 at 60 DAT, 70.2 after harvesting of rice). *Panchagavya* (seedling root dip + one spray at 30 DAT @6% + application through irrigation water at 60 DAT) also helped in improving the fungal population significantly (47.5 at 30 DAT, 66.5 at 60 DAT, 55.3 after harvesting of rice). The results of experiment revealed that increasing the fertilizer levels significantly increased the bacterial and fungal population (table 3) in the rhizosphere but 120% remained at par with 100% RDF level.

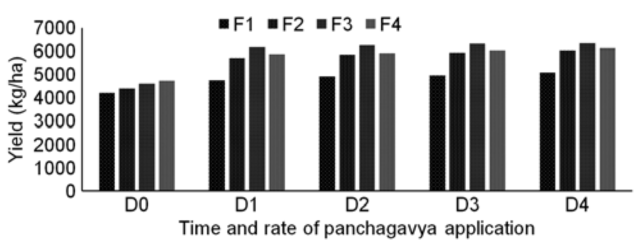

Fig. — 2 Interaction effect of RDF and *panchagavya* on the grain yield of rice

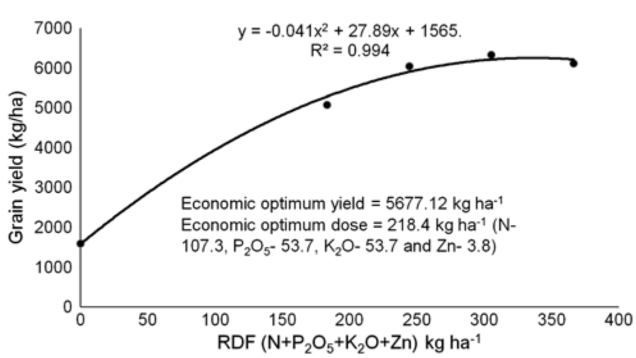

Fig. — 3 Relationship between RDF levels and grain yield of aromatic hybrid rice as affected by *panchagavya*. (*Significant at $P < 0.05$)

SMBC and dehydrogenase activity

The highest SMBC (Table 4) was recorded in rice treated with seedling root dip + one spray at 30 DAT @ 6% + application through irrigation water at 60 DAT. The average increase in MBC with D_4 treatment over control was 19.46, 17.45 and 16.21% during 30 DAT, 60 DAT and at harvest respectively.

The data related to dehydrogenase activity (DHA) as influenced by RDF and *panchagavya* are presented in Table 4 RDF had a significant impact on DH activity (µg TPF/g soil/24 hrs). The highest DH activity was observed in 100% RDF (123.4 at 30 DAT, 142.3 at 60 DAT, 134.0 after harvesting of rice, while the lowest DH activity was observed in 60% RDF treatment. There was a significant difference in DH activity at D_4 (131.2 at 30 DAT, 148.0 at 60 DAT, 142.4 after harvesting of rice) and among the rest of the treatments at 30, 60 DAT and at harvest. *Panchagavya* use as seedling root dip + one spray at 30 DAT @ 6%+ application through irrigation water at 60 DAT was found to be superior in the removal of hydrogen by accounting the highest activity of dehydrogenase at 30, 60 DAT and harvesting stage.

Succeeding lentil

An examination of data (Table 2) revealed that grain yield of succeeding lentil was highly influenced by the residual effect of *panchagavya* which brought about significant improvement in yield over control. *Panchagavya* at D_4 level during preceding rice produced higher grain yield (1738 kg/ha) than other levels and remained statistically at par with D_3. Increment in grain yield under residual effect of D_4 over control was 19.1%. Higher straw yield (Table 2) of succeeding lentil was recorded under residual effect of *panchagavya* at D_4 and it was found

Table 2 — Residual effect of fertilizer dose and time and rate of *panchagavya* application on grain and stover yield of Lentil

Treatment	Grain yield (kg/ha)	Stover yield (kg/ha)
A. Fertilizer dose (4)		
F_1	1422^b	2809^d
F_2	1486^b	3034^c
F_3	1739^a	3275^b
F_4	1829^a	3636^a
B. Time and rate of panchagavya application (5)		
D_{0D} D_0	1406^e	2696^c
D_1	1605^d	3202^b
D_2	1651^c	3271^{ab}
D_3	1694^b	3366^a
D_4	1738^a	3409^a

significantly superior to the rest of the *panchagavya* treatments. The reason was good fertility status of the plot having D_4 and D_3 levels of *panchagavya* treatment during rice.

Significantly higher grain yield of subsequent lentil was recorded by application of 120% RDF (1829 kg/ha) which was 22.25% higher than control. It was obvious from the data (Table 2) that the straw yield of lentil was significantly higher 3636 kg/ha due to residual effect of 120% RDF than rest of the treatments.

Economics

In the *panchagavya* treatments, D_3 registered the maximum treatment cost (579.8 $/ha) followed by D_4 (577.5 $/ha), D_2 (566.3 $/ha) and D_1 (522 $/ha) respectively. Among the RDF levels, 120% (Table 5) registered the maximum input cost (590.6 $/ha) and it was followed by 100% (569 $/ha), 80% (547.4 $/ha) and 60% (525.8 $/ha). The data clearly showed the effect of variables on net return, B:C ratio and profitability of rice, lentil and system basis in Table 5. The highest net return (1200 $/ha), B:C ratio (2.11) and profitability (3.29 $/ha/day) of rice was obtained by application of 100% RDF due to less input cost and among the rate and time of *panchagavya* application D_4 was the best. But in case of economics of lentil crop and system economics maximum net return, B:C ratio and profitability were recorded by application of 120% RDF and among the *panchagavya* levels D_4 treatment was superior due to higher yield of lentil in said treatments.

Discussion

Significant variation was reported among *panchagvya* and RDF with respect to plant height, tillers/hill, dry matter, SPAD and LAI. The possible reason for higher growth characters and increased

Table 3 — Effect of fertilizer dose and time and rate of *panchagavya* application on bacterial and fungal population (colony forming unit-cfu)

Treatment	Bacterial population (cfu×10^5 /g of soil)			Fungi population(cfu×10^5 /g of soil)		
	30 DAT	60 DAT	After rice harvest	30 DAT	60 DAT	After rice harvest
			A. Fertilizer dose			
F_1	44.2^c	62.6^b	53.4^c	39.2^b	45.9^c	39.1^c
F_2	48.4^b	63.6^b	56.7^c	41.8^b	54.8^b	47.8^b
F_3	50.3^b	70.0^a	60.6^b	42.2^b	60.2^a	50.4^b
F_4	51.3^a	72.1^a	63.2^a	44.8^a	61.5^a	51.2^a
			B. panchagavya application			
D_{0D} D_0	38.2^d	39.0^e	32.5^e	34.4^e	32.9^e	34.5^e
D_1	47.1^c	69.3^d	59.7^d	40.1^d	56.6^d	44.6^d
D_2	50.5^b	71.9^c	63.2^c	43.0^c	59.5^c	48.9^c
D_3	52.4^b	75.5^b	66.9^b	45.0^b	62.5^b	52.1^b
D_4	54.8^{ba}	79.8^a	70.2^a	47.5^a	66.5^a	55.3^a

Table 4 — Effect of fertilizer dose and time and rate of *panchagavya* application on soil microbial biomass carbon and on dehydrogenase activity

Treatment	SMBC (µg C/g of soil)			Dehydrogenase (µg TPF/g of soil/24 h)		
	30 DAT	60 DAT	After rice harvest	30 DAT	60 DAT	After rice harvest
			A. Fertilizer dose			
F_1	104.6^b	154.4^b	142.9^b	110.8^b	121.7^b	125.0^b
F_2	109.4^b	160.9^b	148.3^b	116.5^{ab}	135.2^{ab}	127.6^{ab}
F_3	120.9^a	178.0^a	166.0^a	123.4^a	142.3^a	134.0^a
F_4	126.2^a	186.2^a	172.0^a	120.1^a	139.4^a	130.7^{ab}
			B. panchagavya application			
D_{0D} D_0	98.5^b	148.0^b	139.0^b	93.1^d	100.6^d	99.3^c
D_1	116.8^a	170.8^a	157.4^a	118.2^c	137.7^c	131.7^b
D_2	118.7^a	174.4^a	160.7^a	121.1^{bc}	141.3^{bc}	134.4^b
D_3	120.3^a	176.8^a	163.5^a	124.9^b	145.5^b	138.9^a
D_4	122.3^a	179.3^a	165.9^a	131.2^a	148.0^a	142.4^a

Table — 5 Economics of rice-lentil system under different fertilizer dose and *panchagavya* application

Treatments	Rice				Lentil			System economics		
	Cost of cultivation, $/ha	NR $/ha	B:C ratio	Profitability, $/ha/day	NR $/ha	B:C ratio	Profitability, $/ha/day	NR $/ha	B:C ratio	Profitability, $/ha/day
A. Fertilizer dose										
F_1	525.8	893.3	1.70	2.45	533.1	2.18	1.46	1426.4	1.58	3.91
F_2	547.4	1107.6	2.02	3.03	573.4	2.35	1.57	1681	1.80	4.61
F_3	569.0	1200.0	2.11	3.29	704.2	2.88	1.93	1904.2	2.02	5.22
F_4	590.6	1183.6	2.00	3.24	761.8	3.12	2.09	1945.4	2.05	5.33
B. *Panchagavya* application										
D_{0D} D_0	515.4	818.2	1.59	2.24	536.0	2.19	1.47	1354.2	1.53	3.71
D_1	552.0	1141.4	2.07	3.13	634.0	2.60	1.74	1775.4	1.91	4.86
D_2	566.3	1156.7	2.04	3.17	658.4	2.70	1.80	1815.1	1.92	4.97
D_3	579.8	1169.3	2.02	3.20	682.4	2.79	1.87	1851.7	1.95	5.07
D_4	577.5	1194.9	2.07	3.27	704.8	2.89	1.93	1899.7	2.00	5.20

height, tillers as well as dry weight might be due to the presence of growth enzymes like GA 3-oxidase, and GA 2-oxidase in *panchagavya*[17] which favoured rapid cell division and multiplication[18-19] as well as helps in enhancement of biological efficiency(potential to produce yield) of crop plants [20]. Presence of growth regulatory substances such as indole acetic acid (IAA), gibberlic acid (GA3), cytokinin and essential plant nutrients from *panchagavya* caused a stimulatory effect on the growth rate of the crop[21]. The development of leaf area is an important factor that affects crop response to added *panchagavya* and fertilizer. Larger leaf-area aids in more interception of solar radiation leading to higher dry matter production[22]. Plants sprayed with *panchagavya* produced bigger leaves and developed denser canopy[23]. Spraying of *panchagavya*, one before the flower initiation and another during grain filling phase induced quick flowering and high grain setting percentage respectively[12]. *Panchagavya* had profound effect on the SPAD value of rice leaves because it contained kinetin which had a positive role in enhancing leaf chlorophyll content and this in turn enhanced photosynthetic activity and consequently growth and yield[24]. Further the increase in the growth parameters due to the application of *panchagavya* could be attributed to the balanced and continuous supply of nutrients due to good soil condition enriched with profuse number of beneficial microorganism which resulted higher photosynthesis and translocation of photosynthates to the plant.

Among rate of RDF 100 and 120% produced significantly higher plant height, tillers/hill, dry matter and LAI. Vigorous growth of aerial part and increased length of shoot under higher supply of nitrogen was due to high rate of synthesis of protoplasmic proteins[25]. Thus nitrogen application at higher level produced the maximum number of tillers/hill[26]. Phosphorus increased the number of tillers, leaf area index and, consequently, the number of panicles in lowland rice[27]. Obviously the plant supplied with higher NPK and Zn levels produced more leaves and recorded higher plant height as well as accumulation of photosynthates which resulted in higher dry matter production[28].

The easy transfer of nutrients to plants through foliar spray of *panchagavya* was the reason for enhancement in yield attributes. Combined use of *panchagavya* and RDF up to 100% promoted the process of tissue differentiation i.e. from somatic to reproductive phase leading to increased floret number and grain setting. It was reported that yield attributes of several crops could be improved by foliar spray of *panchagavya*[29].

Leaf area index plays a major role in formation of productive tillers. Since leaves are the main factors of photosynthesis and dry matter accumulation is expected that the treatment with optimum LAI will have more crop growth rate (CGR). But excessive leaf area index increases respiration and causes reduction in crop growth rate and net assimilation rate (NAR). Therefore D_4 treatment recorded optimum LAI which helps in producing the highest effective tillers/m^2 because all leaves contributed effectively in photosynthesis. On the other hand, severe reduction in net assimilation at the highest RDF levels was due to excessive leaf and leaf area index causing less solar radiation absorption by the leaves due to shading effect by adjacent leaf and as a result net assimilation rate has been reduced. Therefore, the only those tillers became productive which had optimum leaf area.

Presence of microorganism like bacteria, fungi and actinomycetes in *panchagavya* solution caused its significant multiplication in the field which promotes higher SMBC (Table 4) as well as enzymatic activity (Table 4) of the soil which helps in enhancing the fertility of the soil. The balanced application nutrients and *panchagavya* increased the enzyme activity. The presence of dehydrogenase is observed normally in viable cells which represents the oxidative activity of soil and thus considered as a good indicator of microbial activity and ultimately fertility status of the soil. Higher protein yield was due to the increase in the concentration of N in grains which have modified the proportion of grain constituents.

Chemolithotrops and autotrophic nitrifiers (ammonifers and nitrifers) present in *panchagavya* which colonize in the leaves increase the ammonia uptake and enhance the total N supply[30]. The higher nutrient removal by the crop under *panchagavya* might be due to higher availability of nutrients for a longer time. Phosphorus has been reported to play a vital role in the transformation of ammonical ions into protein molecules[31], thereby increasing the nitrogen removal and protein synthesis. Consequently in the present study, application of *panchagavya* helped in higher removal of phosphorus ion and increased the phosphorus content in grain. The increase in nutrient removal with the increase in fertility levels could be attributed to the better availability of nutrients and their transport to the plant from the soil[32].

Significant variation was also reported among *panchagavya* and RDF treatment with respect to microbial population, SMBC and dehydrogenase activity. This might be attributed to the fact that *panchagavya* was a rich source of beneficial micro-organisms like N-fixers and P-solubilizers[33]. Beneficial microorganisms present in *panchagavya* produced IAA and GA and resulted in improvement in yield by maintaining the fertility of soil[33]. Application of *panchagavya* and *beejamruth* increased rhizosphere microbial population[34]. *Panchagavya* improved soil quality, increased growth and yield of crop due to the presence of effective microorganisms (*Lactobacillus, Saccharomyces, Streptomyces* and *Rhodopseudomonas)*[35].

The increase in microbial population by higher levels of N, P, K and Zn increased the root biomass and root exudates which ultimately provided carbon and energy to the soil microbes resulting into multiplication of its population[36].

Increased microbial biomass carbon recorded in the *panchagavya* treated plot might be due to suitable conditions for microbial growth where this development acted as a good substratum for microbial activity. It was also reported that an increase in microbial biomass under organic management[37]. The robust aboveground biomass is accompanied with an active root system, which releases an array of organic compounds into the rhizosphere[38]. These compounds support the growth of microbial community and result in increased population density with higher level and diversity of functions[39]. The SMBC was the highest under application of 120% RDF but was again at par with 100% RDF at 30, 60 DAT and harvest during both the years. Microbial biomass carbon increased with an increase in doses of inorganic fertilizers which was due to an increase in microbial population[40] and formation of root exudates, soughed off from mucigel cells and underground roots of previous crops[41].

Dehydrogenase activity (DHA) is one of the most adequate, important and sensitive bioindicators, relating to soil fertility[42] which depends on microorganisms abundance and activity[43]. It have also been reported that the application of organics viz., *beejamruth, jeevamruth* and *panchagavya* facilitated higher soil biological activity and dehydrogenase activity[44].

Overall, it is confirmed from above finding that *panchagvya* helps in enhancing soil health by increasing beneficial bacterial and fungal population along with improved SMBC and dehydrogenase activity in the soil. Farmers can easily prepare *panchagavya* which is very cheap at their own and apply on the basis of crop need and ultimately manage the overall fertility of soil. According to the report called “Impact of chemical fertilizers and Pesticides on agriculture and allied sectors in the country-2014-15”, regarding promotion of organic product, *panchagavya* can play an important role in enhancing the fertilizers use efficiency by reducing the doses of fertilizer when applied in combination. It is a well-established fact that chemical fertilizers cannot be completely replaced by organics as without chemicals country like India cannot satisfy the food demand of its ever increasing population. Therefore, balancing the dose of fertilizers along with organic source like *panchagavya* is the need of the hour. *Panchagavya* which also contains enzymes like xanthin oxidase and lysozyme[45] are involved in antibacterial - cum - antifungal mechanisms. Therefore, it has also the capacity to reduce the risk of biotic stress in several crops and can be regarded as a source of clean agriculture.

Conclusion

On the basis of two years of experiments the economic optimum dose of RDFs while applied with D_4 level of indigenous product *panchagavya* was 218.4 kg/ha (N- 107.3, P_2O_5- 53.7, K_2O- 53.7 and Zn- 3.8 kg/ha) for getting economic optimum yield (5677.12 kg/ha) of rice. The integration of 100% RDF with *panchagavya* (seedling root dip + one spray at 30 DAT @ 6% + application through irrigation water at 60 DAT) was the best combination in terms of yield and net returns followed by 100% RDF with *panchagavya* (three sprays at 15, 30 and 45 DAT @ 3%) on the basis of output: input ratio. Microbial population (bacteria and fungi), SMBC and dehydrogenase, were more in *panchagavya* treated plot than control indicating better microbial balance in the soil which ultimately improved the soil health and made the soil more fertile and sustainable. Residual effect of *panchagavya* at D_4 level produced higher grain yield of lentil which was 19% more than the treatment without *panchagavya*.

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