

Sesbania reduces fertilizer use and increase energy efficiency and profits of rice crop

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Agricultural systems face increased problem of food production, especially, in densely populated countries like China, India, Pakistan and Bangladesh. High calorie food crops (rice, wheat, maize and tubers) are extensively grown to meet the energy need of the poor people. Globally, rice, wheat and maize account 42% of calorie intake. Unfortunately, for optimum yield, these crops need high rate of fertilizer application, especially N followed by P and K. These high calorie food crops respond promptly to the application of N. The nutrient element N is universally deficient in soils of hot tropics and subtropics. There is visible improvement in crop greenness, 2 to 3 days after application of N fertilizer. So, the farmers are easily convinced about the benefits of N application. To meet the growing demand of food per unit area, farmers have increased the application of inorganic fertilizers (IF). This has resulted in increased fertilizer production and supply to farmers. In India, the N fertilizer consumption was 18 million tonnes in 2012-13 which was 4.5 times higher than that in 1981-82. India produced 24.5 million tonnes urea (14.7 million tonnes N) in 2015-16 which accounted 82% of total N consumption. Globally, 58% of the increase in N demand between 2014 and 2018 would be from Asia, 22% from America, 11% from Europe, and 8% from Africa. Among the Asian countries, bulk increase in world demand for nitrogen is expected to come from China (18%) and India (17%), followed by Indonesia (6%), Pakistan (4%), Bangladesh (2%) and Vietnam (2%).

Key words: Energy efficiency, Fertilizer use efficiency, Rice, Sesbania

RESULTS of experiment 1 conducted for 3 years (2010-12) at the Research Farm of ICAR-Indian Institute of Water Management located at Mendhasal, Odisha revealed that grain and straw yields of rice were similar with integrated nutrient management using *Sesbania* green manure and inorganic fertilizer (INM) and nutrient management using inorganic fertilizer (IF) only. However, INM helped in reducing energy input by 23.5%, improving energy efficiency by 34.5% and net return by 19.5%. Another experiment conducted for 3 years (2015-17) revealed that ONM (organic nutrient management using *Sesbania* green manure and vermicompost) resulted in reduced rice grain yield (8.1%) but increased net return (8.1%) considering a

higher premium of ₹ 1,750/t paddy grain. The ONM treatment reduced energy input (38.8%) and enhanced energy efficiency (57.4%) as compared to IF. Green manure-cum-cover crop, *Sesbania rostrata*, as a component of ONM and INM for the 6 year study period helped in mean saving of 50.0 kg N, 8.3 kg P₂O₅ and 16.4 kg K₂O/ha. It enhanced energy efficiency and profitability of lowland rice besides improving the organic carbon, available N, P₂O₅ and K₂O content in soil. Considering potential cultivated area of *Sesbania* as green manure in about 20 million ha in irrigated and rainfed lowland ecologies, about 1 million tonne N can be saved which corresponds to 9% of annual urea production in India. A policy should be developed

to promote *Sesbania* green manure by providing an incentive amount of ₹ 1,324/ha to farmers growing this crop which may reduce burden on fertilizer subsidy.

Globally, the crop productivity and profitability is both input and energy intensive. Reactive N plays a central role in food production. On the other hand, it is now strongly felt to rebuild soil health after deterioration of soil properties due to heavy use of chemical fertilizers. There is a great need to conserve soil, water, and nutrients; and minimize the use of IF, fossil fuels, and synthetic pesticides. Government of India has already implemented the policy to use *neem* coated urea in place of prilled urea to reduce the reactive N loss to the environment. Additionally, it has target to reduce urea consumption by



50% by 2022 to reduce soil and environmental pollution and burden on subsidy. Procedure is in place to reduce the weight of urea bags from 50 kg to 45 kg. Considering the importance of the issue, other options for reducing N fertilizer use are welcome. *In-situ* grown green manures in rice crop have substantial role in reducing the fertilizer consumption.

Rice is the staple food for more than the half of the world's population. About 84% of global rice production is used as human food while it is 64% and 14% for wheat and maize, respectively. It is estimated that for every 1 billion people added to the world's population, 100 million tonne more of paddy grain will be needed annually. In most of the developing world, rice availability is equated with food security and closely connected to political stability. There was a lower rice output due to El Nino and prices increased to a record high of US \$1000/t in international market in the 2008. In Asia, there was a crisis of rice availability and our country imposed blanket ban on rice exports to control price in the domestic market. Rice is grown in 44 million ha in India out of which highest area (22 million ha) under irrigated ecosystem followed by 14.4 million ha under rainfed lowland. Assuming cultivation of *Sesbania* as green manure in about 20 million ha in these two ecologies, about 1 million tonne N can be saved at 50 kg N/ha. This corresponds to 9% of annual urea production in India.

Green manures for rice crop is very useful considering low C:N ratio, high N content and easy decomposition in rice growing environment. *Sesbania* as a legume cover-cum-green manure crop, fits into the growing environment preceding wet season rice, especially under medium to lowland situations. As a traditional practice, soils are open during summer ploughing for control of weeds and other pests using the principle of soil solarization. Seeds of *Sesbania* can be sown on the cloddy field with the expected pre-monsoon showers or at least after receiving early monsoon

rainfall. This provides an opportunity to raise green manure-cum-cover crop *Sesbania in-situ*. It acts as cover crop for about 45 to 60 days depending upon the onset of rainfall and/or sowing time. Importantly, it helps to recycle nutrients released from dry tilled soil (after wetting) by capturing through roots. After the long dry season, good amount of N in oxide form is expected to be added from atmosphere (due to combustion of fossil fuels) with the rainfall. Also, by the physical action of lightening, atmospheric inert N₂ is converted to oxide form. Finally, NO₂ reacts with rain water and reaches as HNO₃. *Sesbania* can harvest this benefit and recycle nutrients for rice crop. Also, *Sesbania* as a legume crop adds biologically fixed N in root nodules. As a cover crop, it conserves soil and water. After incorporation of green manure into the soil, earthworm population is observed to increase significantly in medium lands and shallow lowlands. These beneficial conservation agricultural activities can be completed in the fallow period before rice transplanting in mid to end July.

Experiment 1 was conducted in wet season of 2010, 2011 and 2012. Mid duration (135 days) high yielding rice variety '*Surendra*' was used to study the effect of INM (using *in-situ Sesbania* green manure and complimentary need using IF) *vis-a-vis* nutrient management using IF alone on energy efficiency, productivity, profitability and sustainability in rice cultivation. *Sesbania rostrata*, the green manure-cum-cover crop was sown by broadcasting on cloddy field opened with summer ploughing using a seed rate of 20 kg/ha. The seeding time of *Sesbania* varied from latter half of May to June first week depending on weather forecast. The green manure crop was harvested at 45 to 50 days of germination. Fresh biomass yield of 8500, 11500 and 9100 kg/ha were recorded for the respective years with the dry weights of 1631, 2260 and 1700 kg/ha (Table 1). For the INM treatment, mean supply of nutrient through IF (using urea, di-ammonium phosphate and muriate of potash) was 38.3 kg N, 33.2 kg

P₂O₅ and 26.7 kg K₂O/ha. Out of the IF portion, full dose of P and K were provided as basal using di-ammonium phosphate and muriate of potash, respectively. For N, 50% was applied as basal considering the amount added through di-ammonium phosphate and the differential amount using urea. Remaining 50% N was top dressed using urea in two equal splits at tillering and panicle initiation stages. The total nutrient supply through *Sesbania* and IF was 80 kg N, 40 kg P₂O₅ and 40 kg K₂O/ha.

Experiment 2 was conducted in wet season of 2015, 2016 and 2017. Mid duration (135 days) high yielding rice variety '*Vijetha*' (MTU 1001) was used to study the effect of ONM (using *in-situ Sesbania* green manure and vermicompost) *vis-a-vis* IF on energy efficiency, profitability and sustainability in rice cultivation. The green manure crop was harvested at 51, 48 and 46 days of germination for the year 2015, 2016 and 2017, respectively. Fresh biomass yield of 14800, 13500 and 14600 kg/ha were recorded for the respective years with the dry weights of 2790, 2579 and 2788 kg/ha. Mean nutrient supply due to green manuring for this period was 57.9 kg N, 9.9 kg P₂O₅ and 19.3 kg K₂O/ha. After considering the nutrient added using green manure, the mean differential amount of 22.1 kg N, 30.1 kg P₂O₅ and 20.7 kg K₂O/ha (from the recommended dose) was met from application of vermicompost. The mean nutrient content in vermicompost for the study period on dry weight basis was 1.45% N, 0.60% P and 0.76% K. The application rate for vermicompost was 3040, 3097 and 2886 kg/ha for the year 2015, 2016 and 2017, respectively, by considering the average demand for the three major nutrients.

The market price of inputs and outputs was used to work out the cost of cultivation, gross return and net return considering the base year as 2015. Local market price in rupees (₹) of inputs and outputs were considered for this purpose. Price of paddy grain was considered as ₹ 14,500 as per the minimum

Table 1. Weight of *Sesbania* and vermicompost, and amount of organic N, P₂O₅ and K₂O added for rice crop

Item Year	Experiment 1				Experiment 2			
	2010	2011	2012	Mean	2015	2016	2017	Mean
<i>Sesbania</i> fresh weight (kg/ha)	8,500	11,500	9,100	9,700	14,800	13,500	14,600	14,300
<i>Sesbania</i> Dry weight (kg/ha)	1,631	2,260	1,700	1,864	2,790	2,579	2,788	2,719
N, P ₂ O ₅ , K ₂ O from <i>Sesbania</i> (kg/ha)	36.6, 6.0, 11.8	50.0, 7.7, 15.7	38.5, 6.7, 12.5	41.7, 6.8, 13.3	60.0, 10.0, 19.8	55.9, 9.8, 18.8	59.1, 9.8, 19.5	58.3, 9.9, 19.4
N, P ₂ O ₅ , K ₂ O from Vermi-compost (kg/ha)	-	-	-	-	20.0, 30.0, 20.2	24.1, 30.2, 21.2	20.9, 30.2, 20.5	21.7, 30.1, 20.6
N, P ₂ O ₅ , K ₂ O from inorganic fertilizers (kg/ha)	43.4, 34.0, 28.2	30.0, 32.3, 24.3	41.5, 33.3, 27.5	38.3, 33.2, 26.7	-	-	-	-
Total N,P ₂ O ₅ , K ₂ O (kg/ha)	80, 40, 40	80, 40, 40	80, 40, 40	80, 40, 40	80, 40, 40	80, 40, 40	80, 40, 40	80, 40, 40

support price for the financial year 2015-16 guaranteed by the Government of India. For paddy grain grown under organic nutrition, a higher price of ₹ 16,250 was considered. A higher premium for organic paddy at ₹ 1,750 is reported. Local price of paddy straw was ₹ 1,000. Labour charge was considered as ₹ 200 per man-day with effective working period of 6 hour. Price of urea (46% N) as ₹ 6.50/kg, DAP (18% N and 46% P₂O₅) as ₹ 25.50/kg and MOP (60% K₂O) as ₹ 17.50/kg were considered based on retail price in local market for the year 2015. Hiring charge of tractor (including diesel and operator charges) for field preparation was ₹ 550/h.

Rice grain and straw yield

Results of experiment 1 revealed that mean grain yield for the three year study period in INM was 4703 kg/ha and a similar yield of 4610 kg/ha was recorded for the treatment IF (Table 2). Similar results were observed for straw yields of INM and IF treatment. Thus, it can be inferred that the yields were similar with INM and IF. *Sesbania* green manure with low C:N ratio (18:1) and green succulent tissues might have decomposed fast resulting in quick nutrient availability. Green succulent tissues of *Sesbania* having higher N content, protein, water soluble constituents and lower fibre, hemicelluloses, cellulose and lignin content promotes easy decomposition after incorporation in wet soil, especially in hot humid climate prevalent in wet season.

Results of experiment 2 revealed that mean grain yield under ONM

(4463 kg/ha) was 8.1% lower than the IF (4857 kg/ha). The mean straw yield of rice under ONM (5720 kg/ha) was 3.5% lower as compared to IF (5930 kg/ha). *Sesbania* green manure with low C:N ratio (18:1) and succulent tissues might have decomposed fast in presence of complimentary dose of IF resulting in quick nutrient availability. However, when *Sesbania* green manure was integrated with vermicompost, there was initial setback for crop in absence of readily available source of IF. This resulted in reduced dry matter production and subsequently, low straw and grain yield.

Energy analysis

The energy input was reduced by 23.5% when rice was grown under INM (7.8 GJ/ha) as compared to IF (10.2 GJ/ha). *Sesbania* green manure crop reduced energy input mainly due to highest amount of N (41.7 kg/ha) added and very high value of energy equivalent (60.6 MJ/kg).

Also, savings in P and K fertilizers reduced energy input. Further, manual weeding was less under the INM due to smothering effect of *Sesbania* on weeds and also, possibly due to allelopathic effect. On the other hand, growing of *Sesbania in-situ* required only 294 MJ/ha through 20 kg *Sesbania* seeds and 23.5 MJ/ha as human energy for seeding. The crop was grown under rainfed situation and the seeds were sown in cloddy field condition created with summer ploughing. Thus, *Sesbania* cultivation did not require additional cost and energy for land preparation, nor for irrigation. Net energy with the INM practice (137.4 GJ/ha) was higher than IF (131.6 GJ/ha). Energy efficiency was also higher under INM (18.7) as compared to IF (13.9). Grain yield per GJ of energy input was 0.60 t for INM while it was less by 25% for IF (0.45 t GJ⁻¹) indicating higher energy productivity.

In experiment 2, the mean energy input was reduced by 38.8% when

Table 2. Yield, energy and economics of rice with IF vis-à-vis INM (Experiment 1) and IF vis-à-vis ONM (Experiment 2)

Item	Experiment 1 (mean of 3 years 2010 to 2012)		Experiment 2 (mean of 3 years 2015 to 2017)	
	IF	INM	IF	ONM
Grain yield (kg/ha)	4610 ^a	4703 ^a	4857 ^a	4463 ^b
Straw yield (kg/ha)	5917 ^a	6080 ^a	5930 ^a	5720 ^b
Energy input (GJ/ha)	10.2 ^a	7.8 ^b	10.2 ^a	6.2 ^b
Energy output (GJ/ha)	141.7 ^a	145.1 ^b	142.0 ^a	137.1 ^b
Specific energy (t output/GJ)	1.04 ^a	1.39 ^b	1.03 ^a	1.63 ^b
Specific energy (t grain/GJ)	0.45 ^a	0.60 ^b	0.48 ^a	0.71 ^b
Net energy (GJ/ha)	131.6 ^a	137.4 ^b	131.8 ^a	130.9 ^a
Energy output : input ratio	13.9 ^a	18.7 ^b	13.9 ^a	21.9 ^b
Gross return (₹)	72762 ^a	74278 ^b	73505 ^a	78249 ^b
Net return (₹)*	29678 ^a	36709 ^b	25017 ^a	27039 ^b

* Based on price of the base year as 2015. Mean values followed by the same letter for a parameter (within a row) did not differ significantly according to Duncan's multiple range tests (P>0.05).



Table 4. Mean N, P₂O₅ and K₂O added (kg/ha) with equivalent nutrient cost (₹)

Nutrients added	Mean (kg/ha)	*Subsidy Amount (₹)	Equivalent nutrient cost ₹	
			With subsidy	Without subsidy
N	50.0	1044	722	1766
P ₂ O ₅	8.3	68	413	481
K ₂ O	16.4	212	478	690
Total		1324	1613	2937

*Nutrient based subsidy rate for the year 2014-15 in ₹/kg for N=20.875, P=18.679 (P₂O₅=8.157) and K=15.5 (K₂O=12.917)

rice was grown with ONM using *Sesbania* green manure and vermicompost (6.2 GJ/ha) as compared to IF (10.2 GJ/ha). This reduction in energy input (38.8%) was more with ONM as compared to INM (23.5%) as in experiment 1. Mean net energy with IF practice (131.8 GJ/ha) was similar to that with ONM practice (130.9 GJ/ha). Mean grain yield per GJ of energy input was 0.71 t/GJ for ONM while it was 0.48 t/GJ for IF. Highest energy productivity with ONM was associated with 100% savings in synthetic fertilizers and lowest energy productivity with IF was due to the use of 100% of the recommended dose using synthetic fertilizers. Mean energy efficiency was higher by 57.4% with ONM (21.9) as compared to IF (13.9).

Economics

In experiment 1, mean expenditure with INM and IF were ₹ 37,569 and ₹ 43084/ha, respectively. The less expenditure of ₹ 5515/ha with INM was linked to partial savings in IF due to green

manuring. The latter practice required little extra expenditure on *Sesbania* seeds and seeding cost. At similar yield level, less expenditure with INM led to higher mean net return of ₹ 36709/ha as compared to ₹ 29678/ha with IF.

In experiment 2, mean gross and net returns were higher with the ONM as compared to IF by 6.5 and 8.1%, respectively. Mean expenditure with ONM was ₹ 51210/ha while for IF, it was less (₹ 48488/ha). The higher expenditure of ₹ 2722/ha with ONM was linked to higher cost of vermicompost as compared to IF on nutrient basis. Higher returns with ONM as compared to IF, in spite of lower yield and higher expenditure, was due to higher premium for paddy grain grown with organic nutrition by ₹ 1750/t.

Net return with ONM and INM using *Sesbania* as cover-cum green manure crop as compared to the net return with IF is expected to exceed further, if the subsidy on fertilizer is completely withdrawn by the Government. Mean fresh and dry weight of *Sesbania* for six years (2010

to 2012 and 2015 to 2017) were 12.0 and 2.29 t/ha, respectively. This supplied 50.0 kg N, 8.3 kg P₂O₅ and 16.4 kg K₂O/ha (Table 4) which amounts to 62.5% of N, 20.7% of P₂O₅ and 41% of K₂O recommendation for irrigated HYV paddy in wet season. For the year 2015-16, the cost of 50.0 kg N, 8.3 kg P₂O₅ and 16.4 kg K₂O is ₹ 1603 if met using urea, Di-ammonium phosphate and Muriate of potash at subsidized rate controlled by the Government. As per the nutrient based subsidy provided by the Government, the amount of subsidy for the saved quantity of nutrient ₹ 1324. Thus, the cost of saved fertilizer would be ₹ 2937/ha, had there not been subsidy by the Government. A policy should be developed to promote *Sesbania* green manure by providing an incentive amount of ₹ 1324/ha which will reduce burden on fertilizer subsidy.

Residual soil properties

There was build-up of organic carbon, available N, phosphorus and potassium content in soil over the seasons with ONM and INM as compared to IF (Table 5). In Experiment 1, after harvest of third season rice (wet season 2012), organic carbon content in soil increased by 15% from 0.52% to 0.6% with INM. Such increase for ONM (Experiment 2) was 20%. Regarding increase in available N content in soil, it was only 9% for INM while it was 42% with ONM. However, available P₂O₅ content in soil was increased by 56% in case of INM while it was 14% for ONM. A marginal increase of 4% in available K₂O content in soil was noted with INM and also ONM.

Table 5. Residual soil properties with IF vis-à-vis INM (Experiment 1) and IF vis-à-vis ONM (Experiment 2)

Soil property	Experiment 1			Experiment 2 (mean of 3 years 2015 to 2017)		
	Initial	At the end of third year (2012)		Initial	At the end of third year (2017)	
		IF	INM		IF	ONM
Organic carbon (%)	0.52	0.54	0.60	0.40	0.43	0.48
Available N (kg/ha)	224	230	245	215	210.6	304.8
Available P ₂ O ₅ (kg/ha)	20.8	28.5	32.4	38.0	45.5	43.2
Available K ₂ O (kg/ha)	253	260	264	174.7	193.4	182.5

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Know Krishi Unnati Yojana

The *Krishi Unnati Yojana*, a central sector scheme, is envisaged as umbrella programme for focusing on food security, by merging schemes on Soil-health Card, Integrated Scheme on Agricultural Co-operation and Agricultural Marketing, National Mission on Agriculture Extension, Horticulture Development, Price Stabilization Fund, National Mission on Sustainable Agriculture and other programmes.