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## Estimation of nitrogen fixation in nutrient management options under soybean-wheat cropping sequence in an ustochrepts soil

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### Abstract

Soybean- wheat is the dominant cropping system grown on Madhya Pradesh due to congenial climate, development of agro industries and export opportunities. Both are high value crops and raising them using organics may further improve product quality and help in sustaining system productivity on long term basis. A study on impact assessment of nutrient management options and estimation of nitrogen fixation by soybean under different nutrient management options was studied on soybean wheat system. For estimation of nitrogen fixation annual input output N balance technique was used. The experiment was initiated in Kharif 2015 comprising the nine treatments, viz control (no fertilizer and no manure), 100% RDF, 50% RDF + 50% FYM, 50% RDF + 50% VC, 100% FYM, 100% VC, 100% RDF + 25 kg ZnSO<sub>4</sub> (First year), 100% RDF (DAP as a source of P) and 100% RDF + 0.5 kg Ammonium molybdate in both the crops with three replication arranged in a randomized block design. The estimated amount of nitrogen fixed by soybean annually varied from 54.91 to 67.46 kg/ha, however net gain of nitrogen in soil after offsetting the nitrogen derived by soybean ranged from 26.11 kg ha<sup>-1</sup> in control to 9.47 kg ha<sup>-1</sup> in 100% RDF + Zn, 8.99 kg ha<sup>-1</sup> in 100% RDF + 0.5 kg AM, 4.94 kg ha<sup>-1</sup> in 100% RDF, 4.52 kg ha<sup>-1</sup> in 50% RDF + 50% Vermi-compost annually depending upon the mode of nutrient supply kg/ha, annually. Maximum nitrogen gain was recorded 67.46 kg ha<sup>-1</sup> on 100% RDF + Zn nutrient option. There was a linear relationship between the amount of harvestable biomass nitrogen and residual biomass nitrogen. The highest percentage of nitrogen derived from atmosphere(%Ndfa) was recorded in the control treatment, but the highest amount of nitrogen (104.8 kg ha<sup>-1</sup>) fixed was found in the 50% RDF+50% Vermi Compost nutrient option. Conjunctive use of organic and inorganic source of nutrient is the best option to harness the nitrogen fixation potential of soybean.

**Keywords:** Nitrogen fixing capacity, nutrient management, productivity, soybean-wheat

### Introduction

Soybean being a legume crop fixes atmosphere nitrogen and part of that is added to soil through residual biomass which is used by subsequent crop. Soybean is heavy nitrogen feeder and farmers believes that it deteriorate soil fertility. Literature revealed that soybean enriches the soil with nitrogen and organic carbon however, few studies indicated that soybean led to negative balance or very little N is added (Chandel *et al.* 1989; Peoples and Craswell 1992; Singh *et al.* 2008.) Singh *et al.* 2012 reported also addition of 30 –35 Kg ha<sup>-1</sup> biologically fixed N is added to soil by soybean in Vertisols of central India. Based on N<sub>15</sub> dilution technique and N balance technique (Singh *et al.*, 2004, 2008) <sup>[31, 32]</sup> the amount of N fixed by a soybean is influenced by a number of factors including, soil type, varieties, climatic condition and management practices which involves FYM and other nutrients such as P and S (Hardarson *et al.*, 1989) <sup>[6]</sup>. The cost of fertilizer N is increasing with time and saving in N would be a step in the direction of reduction in cultivation cost. Therefore, actual fixation would help in real saving of fertilizer N in subsequent crop. Nitrogen status is also one of the key parameters to assess the fertility status of soil. Correct estimates of N fixation by soybean will not only help in assessing the amount of N added to soil but will also help in assessing the fertility status of soil in developing the strategies for sustainable production. Thus, a study on “Assessment of impact of nutrient management on yield and Soil health under soybean-wheat cropping sequence in an Ustochrepts soil of Central India” is undertaken in Typic Ustochrepts soil at the research farm of Krishi Vigyan Kendra Rajgarh (M.P.) with the aim to quantify

biological N fixation and its contribution to soil.

### Materials and methods

Field experiment was carried out during 2015-16 and 2016-17 at the research farm of Krishi Vigyan Kendra (R.V.S.K.V.V.) Kothibagh, Rajgarh (Biora) under Rajmata Vijayaraje Scindia Krishi Vidhyalaya (R.V.S.K.V.V.), Gwalior, situated in Malwa Plateau at latitude of 24°00'46"N and longitude 76°44'13"E with an altitude of 340 meters from mean sea level (MSL). The climate of experimental site is semi-arid to sub-tropical experiencing dry summer and cold winter. Maximum temperature goes up to 43°C during summer and steep down

to as low as 5 – 6°C during winter. Annual average rainfall of the farm is 1100 mm and most of the rain occurs during second week of June to mid of September. Winter rains are occasional and uncertain. Soil of experimental site belongs to the series *Surjapura*, is medium black, clay loam in texture, dominated with montmorillonite clay and classified as *Typic Ustochrepts* at sub group level. Initial soil properties of experimental site were pH, 7.5; EC, 0.34 dSm<sup>-1</sup>; organic carbon, 0.48%; available nitrogen, 158 kg ha<sup>-1</sup>; phosphorus, 9.1 kg ha<sup>-1</sup>; potassium, 298 kg ha<sup>-1</sup>; sulphur 22.2 kg ha<sup>-1</sup> and Zinc 0.51 mg kg<sup>-1</sup>, respectively.

**Table 1:** Treatment details of experiment

Symbols used	Treatment details	
	Soybean	Wheat
T <sub>1</sub>	Control	Control
T <sub>2</sub>	100% RDF(NPK-20:60:20)	100% RDF(NPK-120:60:60)
T <sub>3</sub>	50% RDF + 50% FYM@2.0t/ha	50% RDF + 50% FYM@ 10 t/ha
T <sub>4</sub>	50% RDF + 50% VC@1.0 t/ha	50% RDF + 50% VC@ 4 t/ha
T <sub>5</sub>	100% FYM@5t/ha	100% FYM@ 20 t/ha
T <sub>6</sub>	100% VC@2t/ha	100% VC@ 8 t/ha
T <sub>7</sub>	100% RDF + 25 kg ZnSO <sub>4</sub> (First year)	100% RDF
T <sub>8</sub>	100% RDF (DAP as source of P)	100% RDF (DAP as source of P)
T <sub>9</sub>	100% RDF + 0.5 kg Ammonium molybdate	100% RDF + 0.5 kg Ammonium molybdate

FYM N = 0.5% P=0.25% K=0.5%, Vermicompost N=1.25% P=0.625% K=1.25%

The recommended dose of fertilizer for Soybean (20:60:20 - N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O kg ha<sup>-1</sup>) and Wheat (120:60:40 - N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O kg ha<sup>-1</sup>) were applied as per the treatments. For application of N, P and K, urea, single superphosphate/ DAP and muriate of potash were used, respectively. The whole amount of nitrogen in soybean and 1/3rd of nitrogen in wheat and entire dose of P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O, Zn, FYM and Vermicompost was applied as basal dose at the time of sowing (before last harrowing). The remaining 2/3<sup>rd</sup> per cent of nitrogen of wheat was top dressed in two equal splits at 30 and 45 days after sowing. In one of the treatments (100% NPK), P was added through DAP to make it S free treatment. FYM and Vermicompost were applied @5 tonnes ha<sup>-1</sup> yr<sup>-1</sup> and @ 2 tonnes ha<sup>-1</sup> yr<sup>-1</sup> before sowing of *kharif* soybean and @20 tonnes ha<sup>-1</sup> and @ 8 tonnes ha<sup>-1</sup> respectively before sowing of *rabi* wheat in both the years as per nutrient composition and amount required. In one of the treatments, required amount of seed was treated with ammonium molybdate @ 0.5 Kg ha<sup>-1</sup>. After each crop, soil samples were collected (0-15 cm depth) and analysed for nutrient status, pH, EC and soil organic carbon (Walkley and Black, 1934) [37]. Each year, plant biomass and grain yields were determined for each plot. Grain and straw sample of soybean and wheat were analyzed for nitrogen uptake by exported biomass in each crop by the Kjeldhal method after pre digestion with H<sub>2</sub>O<sub>2</sub> followed by sulphuric acid (Piper, 1966) [19].

To separate the component of fixed nitrogen annually left in soil, treatment wise % Ndfa value was worked out. To quantify % Ndfa in soybean, we used the following equation based on N input-output balance, including the change in total soil N (dTSN) in the 0-15 cm soil depth (Singh *et al.*, 2004) [29] since the initiation of the experiment:

$$\% \text{Ndfa} = \frac{(\pm \text{dTSN} + \text{HBN}_s + \text{HBN}_w + \text{GL}_n + \text{LL}_n - \text{NSN} - \text{EN})}{(\text{HBN}_s + \text{RBN}_s)} \times 100$$

Where in N ha<sup>-1</sup> yr<sup>-1</sup>

HBN<sub>s</sub> = harvestable biomass N (grain + straw) of soybean

HBN<sub>w</sub> = Harvestable biomass N of wheat,

RBN<sub>s</sub> = residual biomass N of soybean

EN = external N applied through fertilizer and farmyard manure (FYM) and precipitation,

NSN = contribution of non-symbiotic N

GL<sub>n</sub> = gaseous loss of N (as NH<sub>3</sub>, NO<sub>x</sub> and N<sub>2</sub>O) from applied fertilizer and,

LL<sub>n</sub> = leaching loss of N,

dTSN (Kg N ha<sup>-1</sup>) = change in total soil N

When the difference in total soil N between the final sampling and the initial sampling is negative, its depletion, and when the difference is positive, it indicates increase in total soil N, i.e., N added to the soil.

For estimating residual biomass N, we used average harvestable biomass/leaf fall ratio of 5.3:1, harvestable biomass/root biomass ratio of 3.2:1 and root biomass/nodule biomass ratio of 7.6:1 as observed in our earlier study, which was conducted for seven years under similar conditions (Kundu *et al.*, 1997) [15]. Rhizodeposition of N from root exudates was calculated using the values from literature (Shamoot, 1968) [27], Shamoot (1968) [27] observed that rhizodeposition of C from root turnover and exudates represented 5-20% of the above ground biomass in 11 plant species. We considered the middle value (12.5%) of this range as the contribution of C from soybean through rhizodeposition with C/N ratio of 12. The N content in rainwater in this region was quite variable (0.515± 0.175 mg L<sup>-1</sup>). Based on average rainfall during the 33-years period, 7.5 kg ha<sup>-1</sup> yr<sup>-1</sup> was estimated to be the N input through annual precipitation.

We assumed zero value for the contribution of N input (NSN) from diazotrophic bacteria in this experiment, as the role of native diazotrophs in soil as a source of N has remained a controversial issue (Michiels *et al.*, 1989) [16] due to limitations in its measurement. To account for the gaseous loss (GL<sub>n</sub>) of N from fertilizer and FYM, default emission factor of 0.1 kg (NO<sub>x</sub>)-N emitted per kg of fertilizer N and 0.2 kg (NH<sub>3</sub> + NO<sub>x</sub>)-N emitted per kg of FYM-N as

recommended by Intergovernmental Panel on Climate Change (IPCC, 1997), were used. To account for the de-nitrification loss of N as N<sub>2</sub> and N<sub>2</sub>O emission, we used the following Bouwman's equation (Equation 2: Bouwman, 1996);

$$N_{em} = 1 + 0.0125 Na$$

Where  $N_{em}$  is the N<sub>2</sub>O emission and Na is the total amount of N added annually to soil through fertilizer. The value of  $N_{em}$  was multiplied by 0.636 to get the value of N<sub>2</sub>O-N through fertilizer. The value of  $N_{em}$  was multiplied by 0.636 to get the value of N<sub>2</sub>O-N loss from each treatment. The probability of leaching loss of NH<sub>4</sub><sup>+</sup> - N and JNO<sub>3</sub> - N is expected to be very low, as conductivity of soil is very poor (0.006 m day<sup>-1</sup>). If any amount of NH<sub>4</sub><sup>+</sup> - N and NO<sub>3</sub> - N is moved down in the profile, it would be trapped by the subsequent wheat crop having root up to 2.5 m. To account for volatilization losses of N, we use 15% of total N applied from our study (Singh *et al.*, 1996) [15], which was estimated from the laboratory and field through the dynamic air circulation method.

In spite of bounded plots, two-three showers of high intensity were experienced every year and outflow of water was inevitable. To measure the loss of N in runoff (SRL), a plastic pipe of 100-mm diameter channelled water to big plastic container embedded in soil at one corner of the plot. After each heavy rainfall, total volume of water was measured and a sample of water was drawn for the estimation of N.

## Results and Discussion

### Soybean Seed and Wheat Grain Yield (Kg ha<sup>-1</sup>)

The data on soybean seed and wheat grain yield recorded in both the years (2015-16 and 2016-2017) of study presented in table 2 revealed that the seed yield of soybean and grain yield of wheat were significantly affected on application of different treatments through organic, Inorganic and integrated ways. The Mean grain yield of Soybean varied between 1017.5 Kg ha<sup>-1</sup> to 1607.5 Kg ha<sup>-1</sup> and wheat from 2672.5 Kg ha<sup>-1</sup> to 4602.5 Kg ha<sup>-1</sup>. The maximum (1607.5 Kg ha<sup>-1</sup>) seed yield of Soybean was recorded in the treatments received 50%RDF+ 50% VC, followed by 50%RDF+ 50% FYM, 100% RDF + ZnSO<sub>4</sub>, 100% N through VC and 100% N through FYM which were 57.98%, 57.0%, 54.30%, 52.82%, 50.61% higher over control respectively but among themselves all the treatments are statistically at par. This means these treatments had similar effect on yields of soybean. This is due to supply of nutrient more or less in

similar quantity. Perusal of soybean yield data of 2015 indicated that yields are relatively poor than the yield of soybean recorded during 2016. Poor yield of soybean during 2015 is due to excess rain during early stage of growth of crop and early withdrawal of monsoon during 2015-16. Rain fall data recorded and depicted in Fig 1 supports the statement. During mid-July and early August rainfall was 835 mm which water logged the soil for three to four weeks continuously and roots were damaged which resulted poor growth or even death of many plants of soybean as a result of poor aeration. Under this condition soybean roots could not fix N from atmosphere for its growth. After soybean wheat was grown and mean grain yield of wheat was highest (4610Kg/ha) in treatments received from 50%RDF+ 50%VC, followed by 4605 Kg/ha in treatments received nutrient on conjunctive use of chemical fertilizer and organic manure (50%RDF+ 50% FYM) and 100%RDF+ZnSO<sub>4</sub> and these were 72.49% and 72.31% higher over the control. This increased seed yield may be due to higher availability of all the nutrients in balanced manner and better soil health for optimum growth and yield. It has been proved in numbers of reports available that without external supply of nutrient increase in yield is not possible. Application of nutrient is essential to sustain productivity at higher level

A similar effect of nutrient management as that of grain yield was also recorded on straw yield of both soybean and wheat (Table 2). Averaged straw yield of soybean ranged between 1522.5Kg ha<sup>-1</sup> to 2415 Kg ha<sup>-1</sup> and wheat 3515 Kg ha<sup>-1</sup> to 6092.5 Kg ha<sup>-1</sup>. Implementation of various treatments resulted in statistical significant increase in straw yield of both the crops over control when compared with control but are statistically at par among themselves as in case of their respective grain yields.

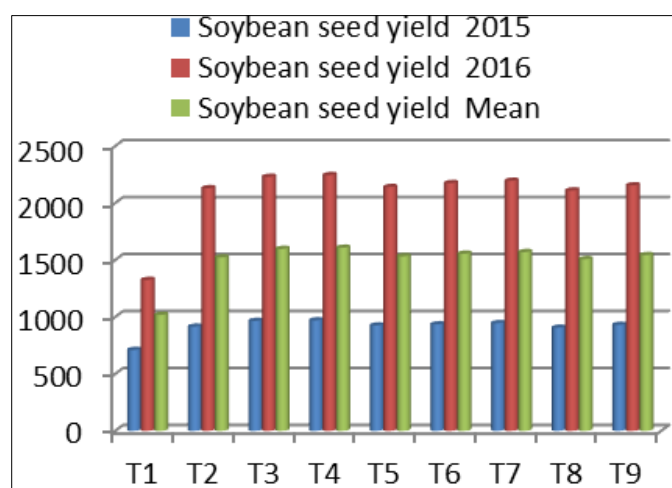
Increase in seed yield of both soybean and wheat on application of nutrient was noted. Increase seed yield is due to more availability of nutrient as per the demand of the crop. Though increase in grain yield of both the crops on conjunctive use of inorganic fertilizer and organic manure is non-significant and increase in yield could be due to rule out of hidden hunger of other nutrients on application of organic manure and also due to better environment for root growth. Tabassum *et al.* 2010, Singh *et al.* 2008 [32], Sawarkar *et al.* 2013 [21] reported better growth of crop and larger yield of both soybean and wheat and incorporation of organic manure further increase the yield.

**Table 2:** Effect of different nutrient management options on grain and straw yield (Kg ha<sup>-1</sup>) of Soybean and Wheat (2015-2017)

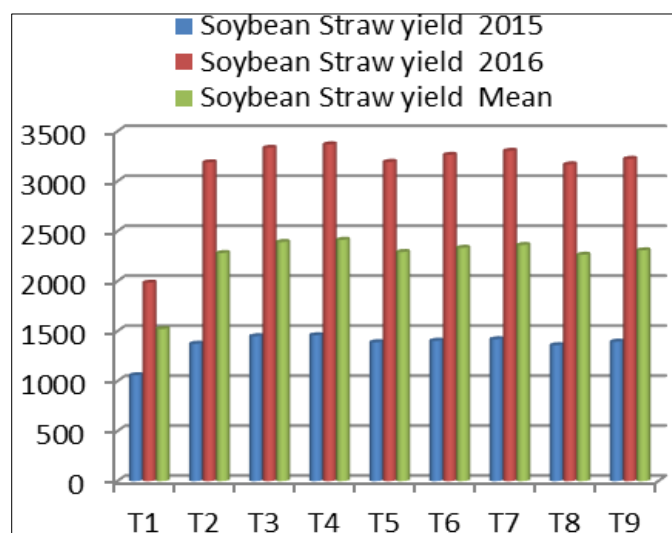
Treatment	Soybean yield(Kg ha <sup>-1</sup> )					
	2015		2016		Pooled Mean of two years	
	Grain	Straw	Grain	Straw	Grain	Straw
T1 Control	710	1060	1325	1985	1017.5	1522.5
T2 100% RDF(NPK-20:60:20)	915	1375	2130	3190	1522.5	2282.5
T3 50% RDF + 50% N through FYM	965	1450	2230	3335	1597.5	2392.5
T4 50% RDF + 50% Vermi Compost	970	1460	2245	3370	1607.5	2415.0
T5 100% N through FYM	925	1390	2140	3195	1532.5	2292.5
T6 100% N through Vermi Compost	935	1405	2175	3265	1555.0	2335.0
T7 100% RDF + Zn (First Year)	945	1420	2195	3305	1570.0	2362.5
T8 100% RDF (DAP as source of P)	905	1360	2110	3170	1507.5	2265.0
T9 100% RDF + 0.5 kg AM	930	1395	2155	3225	1542.5	2310.0
CD 5%	113.1	185.9	233.4	305.1	173.1	250.2
Wheat yield(Kg ha <sup>-1</sup> )						
	Grain	Straw	Grain	Straw	Grain	Straw
	2630	3475	2715	3555	2672.5	3515.0
	4575	6045	4600	6065	4587.5	6055.0
	4595	5975	4615	5990	4605.0	5982.5
	4615	6095	4605	6035	4610.0	6065.0

T5 100% N through FYM	4155	5475	4215	5525	4185.0	5500.0
T6 100% N through Vermi Compost	4175	5510	4220	5525	4197.5	5517.5
T7 100% RDF + Zn (First Year)	4610	6145	4600	6040	4605.0	6092.5
T8 100% RDF (DAP as source of P)	4310	5685	4325	5665	4317.5	5675.0
T9 100% RDF + 0.5 kg AM	4535	5990	4525	5930	4530.0	5960.0
CD 5%	559.2	968.87	912.9	1311.5	456.92	696.18

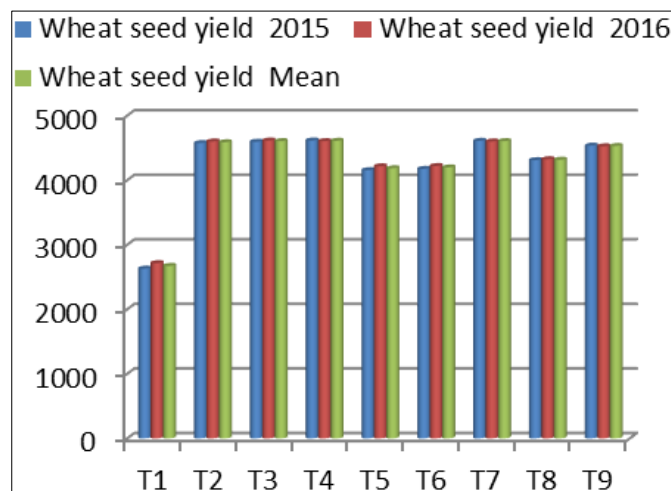
They also reported that application of manure maintained more moisture in root zone for a longer period of time during *rabi* season which helped in increase in yield of wheat. The similar effect of integrated nutrient management was reported by the Gosavi *et al.* (2013) <sup>[5]</sup>, Behra *et al.* (2013) <sup>[1]</sup>, Dadhich and Somani (2007) <sup>[3]</sup>, Venkateswaralu *et al.* (2014) <sup>[34]</sup>, Sharma *et al.* (2013) <sup>[25]</sup>. They concluded that without external supply of nutrient higher productivity can't be achieved and soil health can't be achieved and INM is best way to maintain soil fertility and sustainability as well. Singh *et al.* (2008) <sup>[32]</sup> found the similar results that the soybean seed yield was at par in all 4 modes of nutrient supply system i.e FYM, Poultry manure, FYM cum Fertilizer and fertilizer alone. Wheat grain yield was always lower on exclusive application organic than chemical fertilizer application. Integrated use of FYM and chemical fertilizer not only sustain the yield of wheat but also improve the soil nutrient status. The combined application of organics and chemical fertilizer also lead to larger biological N fixation by soybean and more profit to farmers.



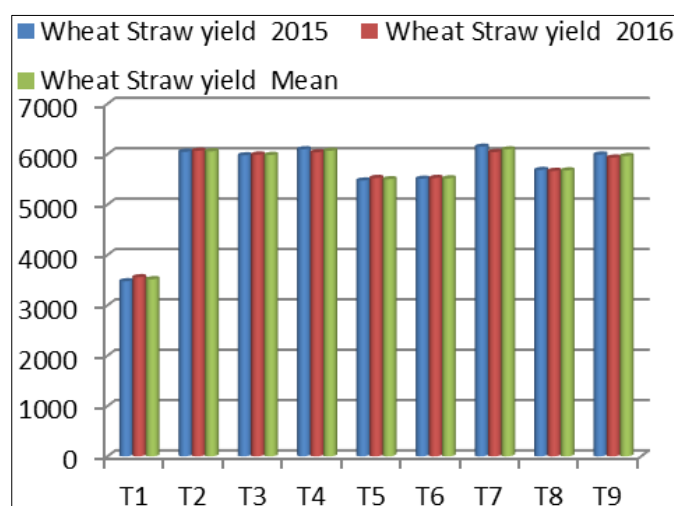
**Fig 1a:** Soybean seed yield Kg ha<sup>-1</sup> in 2015, 2016 and mean seed yield



**Fig 1b:** Soybean straw yield Kg ha<sup>-1</sup> in 2015, 2016 and mean straw yield



**Fig 1c:** Wheat seed yield Kg ha<sup>-1</sup> in 2015-16, 2016-17 and Mean seed yield



**Fig 1d:** Wheat Straw yield Kg ha<sup>-1</sup> in 2015-16, 2016- and Mean straw yield

The results also confirmed the finding of Katkar *et al.* (2011) <sup>[10]</sup>, Sharma and Chauhan (2011) <sup>[25]</sup>, Thakur *et al.* (2011), Prasad *et al.* (2010), Sarawgi *et al.* (2012), Jat and Ahlawat (2004) and Desai *et al.* (1999), Katkar *et al.* (2011) <sup>[10]</sup> reported highest biomass yield in NPK+ FYM amended soil may have been associated with other benefit from N,P and K supply through FYM. Sharma and Chauhan (2011) <sup>[25]</sup> reported that application of Chemical fertilizer in conjunction with manure was the best option as far as productivity is concerned and vermicompost gave better results as compared to FYM due to better nutrient content. Thakur *et al.* (2011) received the 145% more yield of soybean in RDF+15 t FYM over control. Prasad *et al.* (2010) found that 50% N through FYM + 50% N through chemical fertilizer was significantly superior to 100% RDF for wheat crop. Jat and Ahlawat (2004) and Desai *et al.* (1999) found that application of vermicompost along with fertilizer N gave higher dry matter and grain yield of wheat. Thus INM could be better option for sustaining soil productivity.



### Nutrient management and biological nitrogen fixation by soybean and contribution to soil

Biological N fixation by soybean was calculated using input

and output of nitrogen in soil and the details of procedure is described in material and method section

**Table 3:** Parameter values to estimate percentage N derived from atmosphere (%Nd<sub>fa</sub>) in Soybean-wheat system

Treatment	Δ TSN	HBNs	HBNw	HBNt	GLn	Nem	Volatilizatio	SRLn	EN	% Nd <sub>fa</sub>
T1 Control	-9	65.3	41.6	106.9	0	1	0	0	7.5	84.1
T2 100% RDF (NPK-20:60:20)	32	99.2	80.7	179.9	2	2.75	21	14	147.5	63.4
T3 50% RDF+50% N through FYM	37	104.1	80.7	184.9	3	1.875	21	7	147.5	62.2
T4 50% RDF+50% Vermi Compost	38	104.8	81.1	185.9	3	1.875	21	7	147.5	63.0
T5 100% N through FYM	33	99.9	73.5	173.4	4	1	21	0	147.5	51.4
T6 100%N through Vermi Compost	40	101.3	73.8	175.1	4	1	21	0	147.5	55.8
T7 100% RDF + Zn (First Year)	36	102.3	81.2	183.5	2	2.75	21	14	147.5	65.9
T8 100%RDF(DAP as source of P)	33	98.2	75.9	174.1	2	2.75	21	14	147.5	61.1
T9 100% RDF + 0.5 kg AM	37	100.5	79.7	180.2	2	2.75	21	14	147.5	65.8
CD5%	16.9	11.64	7.12	13.12	-	-	-	-	-	13.0

### Component of N Input and Output and %Nd<sub>fa</sub>

Data presented in Table 3 indicate the amount of nitrogen removed by both the crops and loss of nitrogen from soil through different channels varied from treatment to treatments. The amount of nitrogen uptake from soil by crop varied with nutrient management and the figure varied from 106.9 kg ha<sup>-1</sup> minimum in control and maximum 185.9 kg ha<sup>-1</sup> from the plots received 50% RDF +50% Vermicompost. Data further revealed that total nitrogen uptake remain more or less similar/or at par with 50% RDF + 50% Vermicompost.

It is important to note that the change in total nitrogen was positive in all the treatments except in control. The per cent Nd<sub>fa</sub> calculated on the basis of input and output of nitrogen varied from 84.1 to 51.4 percent under different nutrient

management option. This indicates that application of nitrogen resulted in decline in %Nd<sub>fa</sub>, which means application of nitrogen slow down the process of biological fixation of nitrogen by soybean, probably due to availability of nitrogen in soil in large quantity to soybean and the crop use soil N for growth.

### Biologically Fixed Nitrogen by Soybean

Soybean is a legume crop and has ability to fix nitrogen present in atmosphere which is later on distributed to different plant parts including roots. However, quantity of nitrogen fixed by soybean differed in plot to plot. The data indicated that amount of nitrogen (Biologically fixed + derived from soil) added to soil is also varied with nutrient application.

**Table 4:** Average N content (kg ha<sup>-1</sup> yr<sup>-1</sup>) added to soil through residual biomass of soybean crop under different nutrient management option

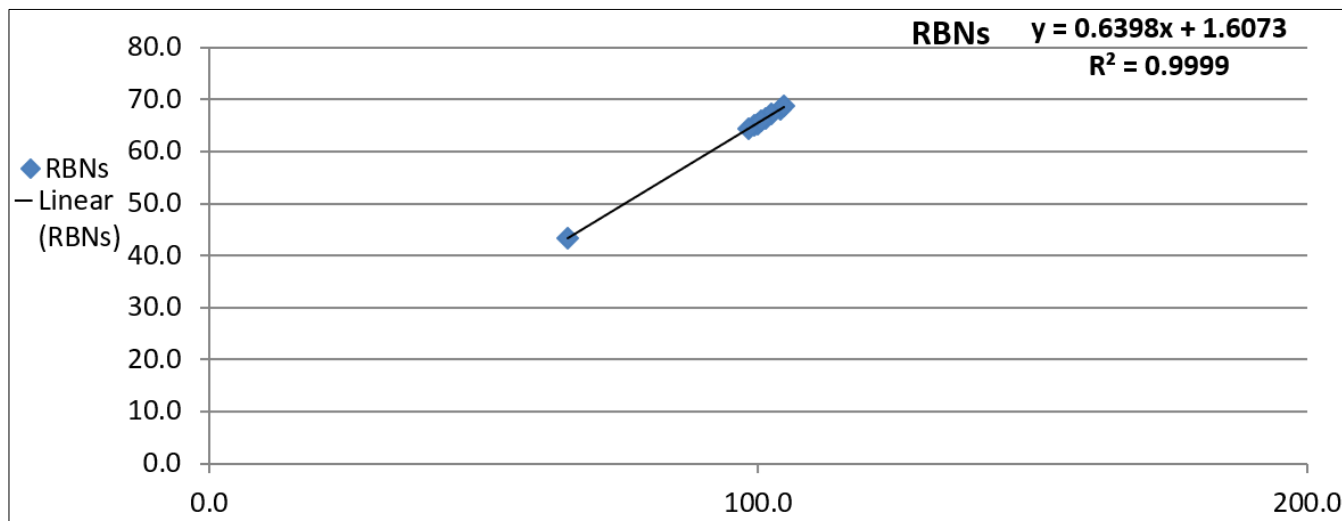
Treatment	Leaf fall	Root biomass	Nodule Biomass	Rhizidposition	Total
T1 Control	2.4	6.2	8.4	26.5	43.4
T2 100% RDF(NPK-20:60:20)	3.6	9.3	12.5	39.6	65.0
T3 50% RDF + 50% N through FYM	3.8	9.7	13.1	41.6	68.2
T4 50% RDF + 50% Vermi Compost	3.8	9.8	13.2	41.9	68.7
T5 100% N through FYM	3.6	9.3	12.6	39.8	65.4
T6 100% N through Vermi Compost	3.7	9.5	12.8	40.5	66.5
T7 100% RDF + Zn (First Year)	3.7	9.6	12.9	41.0	67.2
T8 100% RDF (DAP as source of P)	3.6	9.2	12.4	39.3	64.5
T9 100% RDF + 0.5 kg AM	3.6	9.4	12.7	40.1	65.8
CD5%	0.21	0.56	0.75	2.39	3.92

The total amount of nitrogen added to soil by different components of soybean varied from 43.4 kg ha<sup>-1</sup> (minimum) in control to 68.7 kg ha<sup>-1</sup> (maximum) in plot supplied with 50%RDF + 50%Vermicompost (Table 4). The absolute or actual amount of biologically fixed N added in a treatment will depend on %Nd<sub>fa</sub> of that particular treatment which is described on subsequent section of the text.

### Relationship between Harvestable Biomass and Residual Biomass N

The relationship between harvestable biomass N of soybean

(HBNs Kg ha<sup>-1</sup>) and residual biomass N of soybean (RBNs Kg ha<sup>-1</sup>) is linear (Fig 2 and table 5) which means more is harvestable biomass more nitrogen will be added to soil through residual biomass. Thus, it is inferred that from good soybean crop proportionally more amount of nitrogen is added to soil which is available to next crop and ultimately help in saving of fertilizer nitrogen in next crop and sustaining the soil productivity as well.



**Fig 2:** Relationship in harvestable biomass nitrogen (HBNs) and Residual biomass nitrogen of Soybean in different nutrient management option

**Table 5:** Relationship in harvestable biomass nitrogen (HBNs) and Residual biomass nitrogen of Soybean (RBNs) in different nutrient management options

Treatments	HBNs (Kg ha <sup>-1</sup> )	RBNs (Kg ha <sup>-1</sup> )
T1 Control	65.3	43.4
T2 100% RDF(NPK-20:60:20)	99.2	65.0
T3 50% RDF + 50% N through FYM	104.1	68.2
T4 50% RDF + 50% Vermi Compost	104.8	68.7
T5 100% N through FYM	99.9	65.4
T6 100% N through Vermi Compost	101.3	66.5
T7 100% RDF + Zn (First Year)	102.3	67.2
T8 100% RDF (DAP as source of P)	98.2	64.5
T9 100% RDF + 0.5 kg AM	100.5	65.8
CD5%	11.64	3.92

#### Actual Quantity of Biologically Fixed N Added to Soil

Data presented in table 6 gives an idea about how much actually biologically fixed N added to soil after offsetting the nitrogen derived by above ground parts (grain + straw) of soybean. Total amount of nitrogen fixed by soybean varied from 54.91 kg ha<sup>-1</sup> in control to 67.4 kg ha<sup>-1</sup> (maximum) in the plot received 100% RDF + Zn. Though the values of other treatments observed are more or less similar except of control

and the plot received all nitrogen through FYM. Data further revealed that maximum amount of biologically fixed nitrogen added to soil is 26.11 kg ha<sup>-1</sup> in control plot and the nitrogen added in other treatment ranged from 1.18 kg ha<sup>-1</sup> to 9.47 kg ha<sup>-1</sup>. It is interesting to note that in spite of less fixation of nitrogen, control plot contributed maximum amount of nitrogen to soil which is due to less removal of nitrogen from soil and larger %Ndfa.

**Table 6:** Mean annual input-output of N (kg/ha) in Soil due to soybean and fixed N accredited to soil by Soybean

Treatment	Total annual N uptake A	Fixed N in above ground biomass B	N derived from soil in above ground biomass C=(A-B)	Biologically fixed N added to Soil D	Net N balance gain by soil E=(D-C)
T1 Control	65.3	54.91	10.4	36.50	26.11
T2 100% RDF(NPK-20:60:20)	99.2	62.91	36.3	41.23	4.94
T3 50% RDF + 50% N through FYM	104.1	64.80	39.3	42.43	3.11
T4 50% RDF + 50% Vermi Compost	104.8	66.00	38.8	43.30	4.52
T5 100% N through FYM	99.9	51.30	48.6	33.57	-15.00
T6 100% N through Vermi Compost	101.3	56.52	44.8	37.08	-7.73
T7 100% RDF + Zn (First Year)	102.3	67.46	34.8	44.31	9.47
T8 100% RDF (DAP as source of P)	98.2	60.01	38.2	39.39	1.18
T9 100% RDF + 0.5 kg AM	100.5	66.16	34.3	43.33	8.99
CD5%	11.64	11.20	12.97	7.63	20.17

In some of the plots like 100% FYM and 100% Vermicompost contribution of biologically fixed nitrogen is negative which means that the amount of N (biologically fixed) added to soil is less than the amount of nitrogen derived from soil by above ground portion (grain + straw) of soybean. Thus application of N in large quantity may hamper the process of biological N fixation and will derive N from

applied sources which in turn will led to negative balance of N in soil.

Decline in biological nitrogen fixation on application of nitrogen fertilizer is noted which is due to application of nitrogen in more quantity and plant did not fix nitrogen and secondly due to more absorption of nitrogen by above ground biomass as a result of more productivity and growth of above

ground part. Soybean has very high content of nitrogen in seed which act as good sink of nitrogen and encouraged the plant to derive more nitrogen from soil which is easily available from fertilizer/manure. Decline in biological nitrogen fixation on application of nitrogen fertilizer is due to availability of more nitrogen in soil which did not allow soybean to fix nitrogen. Thus from the results it is concluded that application of nitrogen excess in legume crop may reduce the efficiency of crop to fix nitrogen from atmosphere and would led to negative balance of nitrogen. In literature large number of references are available which indicate negative balance of nitrogen and more true when grain yield of legume crop is very high which derives more nitrogen from soil to fill the grain. Similar results were also found by Singh *et al.* (2012) in Vertisol and Singh *et al.* (2014) in Alfisol under long term fertilizer experiments. Singh *et al.* (2012) study for N<sub>2</sub> fixation and annual input-output N balance technique was used. The estimated amount of N<sub>2</sub> fixed by soybean annually varied from 62.8 kg ha<sup>-1</sup> to 161.1 kg ha<sup>-1</sup>. However the net gain of N in soil after offsetting the N derived by soybean from soil varied from 24.2 to 66.5 kg ha<sup>-1</sup> annually. Maximum N gain was recorded on application of P. There was a linear relationship between the amount of harvestable biomass N and residual biomass N, whereas quantity of N added to soil has a curvilinear relationship with the harvestable biomass N. The highest percentage of N derived from the atmosphere (% Ndfa) was recorded in the control treatment, but the highest amount of N<sub>2</sub> fixed was found in the 100% NPK treatment. Balanced use of nutrient is the best option to harness the N<sub>2</sub> fixation potential of soybean.

## Conclusions

Application of nutrient irrespective of organic and inorganic source is essential to sustain the productivity. Though soybean can be grown with exclusive use of organic manure but to sustain the productivity of subsequent wheat crop there is need to supply of nutrient through inorganic. Thus conjunctive use of both inorganic and organic source in the ratio of 1:1 nutrient was found to be the best option to sustain productivity of both the crop in sequence. Application of nutrient also increased biological fixation of N by soybean and part of biological fixed N by soybean added to soil which may reduce the application of N in subsequent crop. In this study biological N fixation ranged from 54.91 kg ha<sup>-1</sup> to 67.46 kg ha<sup>-1</sup> and the amount of biological fixed N added to soil after offsetting N derived by above ground part of soybean ranged from 26.11 kg ha<sup>-1</sup> in control to 9.47 kg ha<sup>-1</sup> in 100% RDF + Zn, 8.99 kg ha<sup>-1</sup> in 100% RDF + 0.5 kg AM, 4.94 kg ha<sup>-1</sup> in 100% RDF, 4.52 kg ha<sup>-1</sup> in 50% RDF + 50% Vermicompost annually depending upon the mode of nutrient supply.

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