

## Annual nitrogen input to the soil from left-over biomass of soybean (*Glycine max*) in a long-term fertilizer experiment in mid-hills of north-west Himalayas

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### ABSTRACT

Average annual N inputs to the soil through left-over biomass (leaf fall and nodulated roots of soybean [*Glycine max* (L.) Merr.] under different fertilizer and manurial treatments were estimated from a long-term fertilizer experiment initiated in 1973 at VPKAS (ICAR), Almora. Annual biomass N input to soil from soybean through leaf fall, roots and nodule varied from 3.55 to 36.49, 14.10 to 47.69 and 2.98 to 15.21 kg/ha respectively. Continuous application of farmyard manure (FYM) @ 10 tonnes/ha in combination with recommended dose of NPK increased N input to the soil by 46.2 kg N/ha over that observed in NPK treatment (53.19 kg N/ha). Annual total N input to soil through all sources (left-over biomass of soybean, fertilizer and FYM) ranged between 20.63 kg N/ha in control and as high as 175.17 kg N/ha in NPK-FYM treatment. Regression analysis between seed yield of soybean (Y) and total annual N input (X) showed quadratic relationship in the form of  $Y=227.4 + 16.72 X - 0.0149 X^2$  ( $R^2=0.9665$ ). Continuous addition of N through FYM and left-over biomass of soybean over the period of 27 years not only resulted in marked increase of total N content in soil from initial value of 0.45 g N/kg soil to 1.13 and 1.36 g N/kg soil, but also caused significant reduction in C:N ratio from initial value of 12.66 to 9.44 and 8.24 in N-FYM and NPK-FYM treatments respectively.

**Key words :** Soybean, Biomass N, Total N input, Yield response

Long-term sustainability of agricultural system must rely, as much as possible, on use and effective management of nitrogen-fixing plants which offer an economically viable and ecologically sound means of reducing external N inputs (Bohlool *et al.*, 1992) for the succeeding crops grown in

rotation. High-productivity crops, such as soybean contributes considerable amount of N to the soil through left-over biomass even after the removal of harvestable biomass (trash and seed) from the field. The left-over biomass of soybean comprised shaded leaves (after senescence) and nodulated

roots, in addition to organic biomass contributed through fine root decay and exudes during the growing period. Leaf fall during crop legume development and the nodulated roots can each contain up to 40 kg N/ha (Bergersen *et al.*, 1989; Buresh and De Datta, 1991) and yield benefit of the succeeding non-legume crops are very often attributed to the residual fixed N locked in the left-over crop biomass. The annual entry of N to the soil through left-over biomass of soybean is dependent on the level of crop productivity, whose tonnage is determined by level of external fertilizer and farmyard manure (FYM) applied to the crop. Therefore, in the present investigation an attempt was made to estimate the annual N input to the soil through leaf fall and nodulated roots based on average soybean yield obtained from different fertility levels over 27 years.

#### MATERIALS AND METHODS

A fixed-plot (5.4 m x 2.0 m) long-term fertilizer experiment involving 'Bragg' soybean-'VL 616' wheat rainfed crop rotation was initiated in 1973 on an Inceptisol (pH 6.2, EC 0.20 dS/m, CEC 8.72 C mol (+)/kg, bulk density 1.32 Mg/m<sup>3</sup>, clay 5.8%, organic C 0.57%, total N 0.045%) at the experimental farm of VPKAS (ICAR), Almora (29°36'N and 79°40'E with 1,250 m above mean sea-level). The experiment involved 6 treatments with 6 replications distributed in randomized block design over 3 levelled terraces. The treatments were control, 20 kg N + 80 kg P<sub>2</sub>O<sub>5</sub>/ha (N,P), 20 kg N + 40 kg K<sub>2</sub>O/ha (N,K), 20 kg N + 80 kg P<sub>2</sub>O<sub>5</sub> + 40 kg K<sub>2</sub>O/ha (N,P,K), 20 kg N + 10

tonnes FYM/ha (N-FYM) and N,P,K + 10 tonnes FYM/ha (NPK-FYM). Every year all the fertilizers (N as urea, P as single superphosphate and K as muriate of potash) and manures were applied to the soil before the sowing of soybean crop. Harvestable above-ground biomass (trash and seed) of soybean was removed every year and dry weights were recorded.

The soybean crop contributed C input to the soil through leaf fall, roots and nodule biomass. Treatment-wise leaf fall biomass was collected over 3 years (1988, 1990 and 1991). Computation of root biomass and nodule biomass under different treatments was done on the basis of root : shoot and nodule : root biomass ratios observed in our pot culture experiment conducted in 1989 using the same soil collected from the different treatments of the same field experiment. During 1999, treatment-wise biomass samples of leaf fall (collected after senescence), and nodulated roots (sampled through single plant excavation at physiological maturity) were collected and analysed for total N content using CHN-analyser.

Treatment-wise total N input annually added to the soil through fertilizer (20 kg N/ha), FYM (55.83 kg N/ha) and left-over biomass of soybean crop for the 6 replications under each treatment were computed and correlated with the treatment-wise seed yield of soybean (based on 27-year average). Several estimations revealed that the applied FYM contained on an average 32.54% moisture, 23.52% C and 0.73% N.

After the harvest of the 27<sup>th</sup> soybean crop, treatment-wise soil samples were

collected, dried and ground to pass through 0.2 mm sieve for analysis of total organic C and total N in CHN-analyser.

## RESULTS AND DISCUSSION

Estimated average annual organic biomass inputs from soybean through leaf fall, root and nodules under different treatments showed (Table 1) large variation due to differential biomass yield response of soybean to applied fertilizers and manurial input over the period of 27 years. Based on 3-year average leaf-fall data, it was observed that annual entry of organic biomass through leaf fall ranged from 144 to 1,254 kg/ha (Table 1). Regular application of farmyard manure @ 10 tonnes/ha in combination with recommended doses of NPK or even 20 kg N/ha showed marked increase in leaf-fall biomass to 33.3 and 26.5% over that observed in NPK treatment.

For computing the root and nodule biomass of soybean, the treatment-wise root : shoot and nodule : root biomass ratios (Fig. 1) were used which were observed in a pot experiment conducted during 1989 using the same cultivar and soil. The root : shoot ratio ranged between 0.304 and 0.422 and the ratios observed in the control, NP and NK treatments were significantly higher than those observed in NPK, N-FYM and NPK-FYM treatments. Based on all the treatments, the average root : shoot ratio was 0.379. The ratio of nodule : root biomass ranged from 0.113 to 0.153 and the treatment effect on nodule : root biomass ratios was found non-significant.

The annual entry of root and nodule biomass to the soil ranged from 641 to 2,338 and 73 to 313 kg/ha respectively.

Because of the beneficial effect of continuous application of FYM, biomass input through nodulated root increased by 20 and 60% in N-FYM and NPK-FYM treatments, respectively, over that observed in NPK treatment (Table 1). On an average (of all the treatments), nodule-root biomass constituted 25.67% of the above-ground biomass of soybean Kemper *et al.* (1998) observed that in soybean, around 13% of the total organic matter (roots and tops) was found in roots alone at the end of growing season.

Based on mean value (of all the treatments), it was noticed that organic biomass to the tune of 431.6, 879.7 and 118.9 kg/ha was annually added to the soil through leaf fall, roots and nodules for every 1,000 kg seed yield of soybean. Marked reduction in organic biomass addition in NP and NK treatments as compared to NPK treatments (Table 1) was because K and P limited the growth of soybean, which in turn indicates adverse effect of withdrawing K and P application to soil in long run.

The N contents of the shaded leaves, roots and nodules of soybean showed variations, depending on the fertilizer and manurial inputs (Fig. 2). Maximum N content in leaves was observed in NPK-FYM treatment, followed by N-FYM treatment and these were significantly higher than that observed in NPK treatment. Significant reduction in leaf N content in NP and NK treatments was possibly due to nutrient imbalances in soil. The root biomass showed similar N contents in control, NP, N-FYM and NPK-FYM treatments, while significant reduction in N content of roots was

observed in NK and NPK treatments, indicating higher translocation of N from roots to shoots in presence of higher K in soils. The N content of the nodule biomass was also markedly influenced by the fertilizer and manurial treatment (Fig. 2), ranging from 3.26% in NK treatment to as high as 4.86% in NPK-FYM treatment. Pan and Smith (2000) reported that N content in nodules was 3.71-4.57% in some genotypes of soybean.

Based on the estimated average annual organic biomass of leaf fall, roots and nodules and their observed N contents, the average annual N input to soil from soybean (Table 1) was computed. Because of the marked treatment effects, the annual N inputs to soil through leaf fall, root and nodule biomass varied considerably, ranging from 3.55 to 36.49 kg/ha, 14.10 to 47.69 kg/ha and 2.98 to 15.21 kg/ha respectively. With the increase in total biomass yield, per cent contribution of N input through leaf fall increased but contribution from root biomass decreased,

while the contribution from nodule biomass remained more or less same (Table 1).

In addition to N input added through left-over biomass of soybean, the soil under different treatments received N input through fertilizer and FYM every year. Computation of total N inputs through all the sources revealed that on an average 20.63, 55.36, 38.45, 73.17, 153.29 and 175.17 kg N/ha were added to the soil every year under the control, NP, NK, NPK, N-FYM and NPK-FYM treatments respectively. The regression study relating the treatment-wise average seed yield (27-year mean) of soybean with average annual total N input data for 36 plots respectively showed (Fig. 3) that yield response of soybean to total N input followed quadratic response in the form of  $Y = 227.4 + 16.72 X - 0.0149 X^2$  ( $R^2 = 0.9665$ ), where Y was the average annual seed yield of soybean (kg/ha) and X was the total annual N input (kg N/ha) to the soil. The results, thus, provided evidence to indicate that soybean crop responded well to N input applied

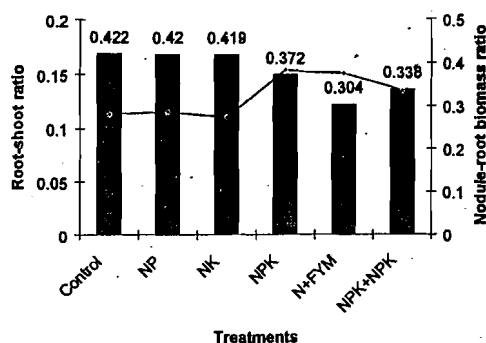


Fig. 1. Root-shoot and nodule-root biomass ratios in soybean under different fertilizer and manurial treatments

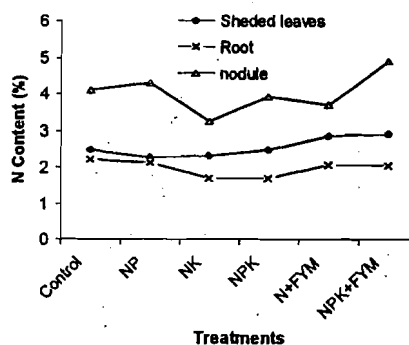


Fig. 2. Nitrogen content of shedded leaves, roots and nodules of soybean fertilizer and manurial treatments

**Table 1.** Average annual N input to the soil from left-over biomass of soybean under different fertilizer and manurial treatments

Treatment	Harvestable biomass yield (kg/ha)	Average biomass addition to soil (kg/ha) through			Annual N input (kg/ha)				Average N input to soil for each kg seed produced (g N/kg seed)
		Leaf fall	Root	Nodule	Leaf fall	Root	Nodule	Total	
Control	1,520 (652)*	144	641	73	3.55 (17.21)**	14.10 (68.35)	2.98 (14.44)	20.63	31.64
NP	2,420 (980)	390	1,016	117	8.81 (24.91)	21.54 (60.92)	5.01 (14.17)	35.36	36.08
NK	1,843 (733)	132	772	90	3.05 (16.10)	12.97 (68.45)	2.93 (15.45)	18.95	26.67
NPK	3,804 (1,580)	836	1,437	220	20.56 (58.66)	23.99 (45.12)	8.62 (16.22)	53.17	32.73
N-FYM	5,686 (2,302)	1,137	1,729	259	32.17 (41.53)	35.79 (46.20)	9.50 (12.27)	77.46	33.65
NPK-FYM	6,918 (2,776)	1,254	2,338	313	36.49 (36.71)	47.69 (47.98)	15.21 (15.31)	99.39	35.80
Mean	3,698.5 (1,503.8)	648.2	1322.2	178.7	17.43	26.01	7.37	50.82	32.76
CD (P=0.05)	308.0 (132)	57.4	1,22.5	18.6	2.16	2.35	1.04	4.96	3.11

\*Data in the parentheses indicate seed yield of soybean based on 27-year average; \*\*data in the parentheses indicate per cent contribution of N input by each biomass component of soybean.

**Table 2.** Status of total organic C and total N in soil (<0.2 mm fraction) after 27 years of soybean-wheat cropping

Treatment	Total organic carbon (g/kg soil)	Total N (g/kg soil)	C : N ratio in soil
Initial soil	5.77	0.45	12.82
Control	6.22	0.56	11.11
N-P	7.33	0.67	10.85
N-K	5.53	0.53	10.47
N-P-K	6.89	0.63	10.93
N-FYM	10.67	0.75	14.12
NPK-FYM	11.12	0.83	13.43
CD (P=0.05)	0.71	0.06	0.88

largely through bio-organic forms such as left-over biomass of soybean and FYM. Similar results were also reported by Kundu *et al.* (1996) and Singh *et al.* (1998). The variable amount of N input, ranging from

18.95 to 99.39 kg/ha (Table 1), annually added to the soil through left-over biomass of soybean in addition to N added through fertilizer and FYM over the period 27 years resulted in the improvement of soil-organic

C and total N status in the surface soil to a variable magnitude, depending on the quantum of bio-organic N input (as FYM and left-over biomass of soybean) added to the soil. All the treatments showed significant improvement in total N content in soil after 27<sup>th</sup> crop cycle. Total N content in soil under NP, NPK, N-FYM and NPK-FYM increased from initial content of 0.45 g N/kg soil to 0.67, 0.66, 1.13 and 1.36 g N/kg soil, respectively, while in the control and NK treatment total N content increased marginally but significantly (Table 2). Continuous addition of organic N through FYM and left-over biomass of soybean over the years in N-FYM and NPK-FYM resulted in marked reduction in C:N ratio in soil from initial value of 12.66 to 9.44 and 8.24 respectively (Table 2), indicating considerable improvement in total N content in those treatments. Even other

treatments which did not receive any FYM, also showed significant reduction in C:N ratio in soil which could be attributed to the N addition to soil through left-over biomass of soybean over the 27-year period.

Thus the results showed that the left-over biomass of soybean annually added variable amounts of total N, ranging from 18.95 to 99.39 kg/ha, in response to different fertilizer and manurial treatments (Table 1). Continuous application of 10 tonnes FYM/ha in combination with recommended doses of NPK or in combination with starter dose of N (20 kg N/ha), not only increased the total N input through left-over biomass by 46.2 and 24.3 kg N/ha over that observed in NPK treatment, but also justified the importance of organic manuring even in legume crops like soybean. Based on the average seed yield and total N input of the experiment, it was

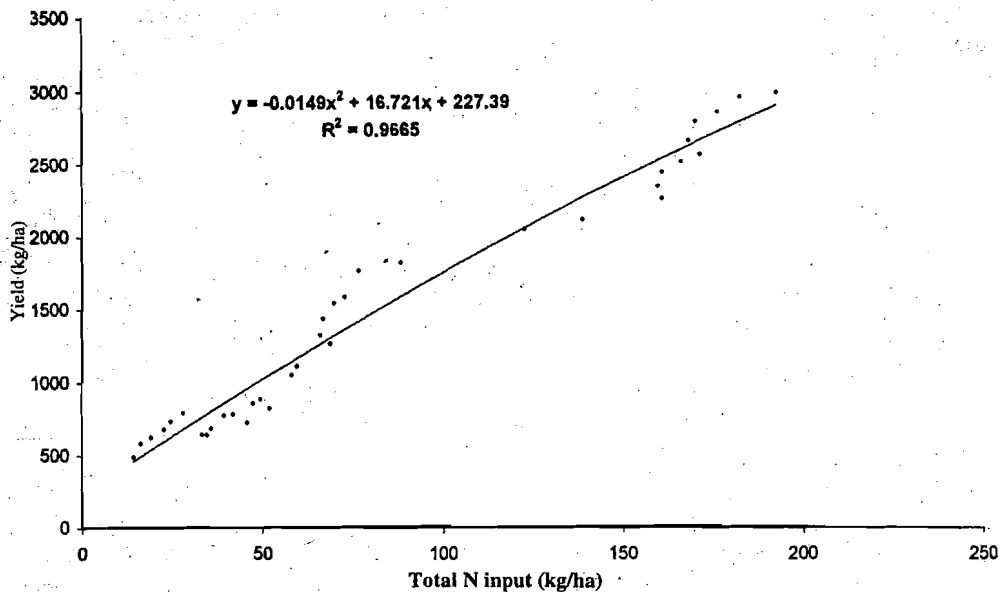


Fig. 3. Relationship between average seed yield of soybean and average total annual N input to soil

observed that 32.76 kg N/ha was added to the soil for every 1,000 kg/ha seed yield of soybean. The results further indicate that while estimating net N balance for crops like soybean, it is desirable to include the contribution of N by leaf fall and nodulated root biomass to get an accurate estimate of the net N balance.

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