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**Research Article** *Natural Resource Management*

# Integrated Nutrient Management on Growth, Yield, Nutrient Uptake and Fertility Balance in Soybean (*Glycine max* L.) – Wheat (*Triticum aestivum* L.) Cropping Sequence

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***Data Availability Statement:*** Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

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## Abstract

A field experiment was conducted at Krishi Vigyan Kendra, Chitrakoot, Uttar Pradesh state, India to assess the effect of Integrated Nutrient Management on Soybean [(*Glycine max* (L.) Merrill] – Wheat (*Triticum aestivum*) for productivity, nutrient uptake and fertility balance during 2008-09 and 2009-10. 18 treatment included use of 50, 75, 100% NPK to soybean and wheat with combination of FYM, Vermicompost and cow pat pit (CPP) were tested. All growth parameters were recorded significantly higher with the application of 100% NPK through fertilizer+5 t $ha^{-1}$ FYM during 2008-09 and 2009-10. Pooled Seed yield (2.52 t $ha^{-1}$), straw yield (2.54 t $ha^{-1}$), nutrient uptake (216.35 kg N, 34.70 kg P and 89.50 K kg $ha^{-1}$) of soybean were also found significantly higher with the same application. The growth parameters of wheat have been found significantly higher with 100% NPK to wheat+residual effect of 50% NPK and FYM @ 10 t $ha^{-1}$ in the kharif crop during two years. Pooled Seed yield (4.95 t $ha^{-1}$), straw yield (4.99 t $ha^{-1}$) and harvest index (49.75 %) of wheat were also obtained highest with same treatment combination during experiment. The soil nutrient status after harvest of second year wheat crop, the available N, P and K in soil were analyzed significantly higher under 100% NPK with residual effect of FYM @ 10 t ha-[1] + 50% NPK over rest of the treatments.

***Keywords:*** INM, growth, yield, soil fertility, soybean-wheat sequence

## 1. Introduction

The maximum cost involvement in cereal–cereal crop rotation has created constraints for labour, inputs supply and net income. Use of inadequate water and chemical fertilizers have led to problem of soil degradation under this system. The continuous growing of rice has led to a deterioration in soil quality, resulting in a serious threat to agricultural sustainability. Therefore, crop diversification with a wider choice in the production of crop varieties is being promoted in different parts of the country (Jat et al., 2012). Considering these issues as a threat to sustainable and profitable agriculture attempt is being made to discover some alternative in the region (Bhatt et al., 2016). Both wheat and rice crops are grown under lavish environment. The green crops with higher dose of N-fertilizers and wet conditions because of frequent irrigations are the paradise for the outbreak of insect-pest and diseases (Saroch et al., 2005). Diversification of rice-wheat cropping system may improve

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the productivity and sustainability of agricultural production in the Indo-Gangetic plane region (IGPR), but the choice of alternative sequences to be used requires integrated assessment of various crop sequences (Singh et al.,2011). Outbreak of the diseases and insect-pests attack is mainly responsible for the lower water and land productivity and is considered a serious issue in the way to sustainable agriculture (Kukal et al., 2014). Soybean (*Glycine max)* - Wheat (*Triticum aestivum*) system has emerged as a predominant cropping system in Bundelkhand region under both irrigated and rainfed conditions. The farmers prefer soybean as a cash crop followed by wheat as a high yielding food grain crop (Chandel et al., 2014). The productivity of these crops has been stagnated or even showing a decreasing trend, even in spite of intensive efforts. Productivity of crops is highly influenced by nutrition specially with organic (Pandey and Kumar, 2017). The efficiency of input use viz. water, fertilizers, herbicides and others depend on tillage and crop establishment practices. It is therefore, essential that the soil environment be manipulated suitably for ensuring a good crop stand and improve resource-use efficiency. Sustaining production and productivity of any system is of paramount importance by improving the soil's physical, chemical and biological properties (Karunakaran and Bahera, 2017). Imbalance nutrition is one of the important constraints of low soybean productivity in north Indian plains (Singh and Singh, 2018). Now a day's organic sources of nutrients are playing important role to enhance crop yields and meet global food demand (Timsina, 2018). The demand for food grains is expected to rise not only as a function of population growth but also as more and more people cross the poverty line with economic and social development (Parewa et al., 2019). The increase in grain yield of wheat due to balanced fertilization is attributed to improvement in growth and yield attributes, which in turn resulted in higher translocation of photosynthates and nutrients, ultimately reflected into higher grain and straw yield ((Das et al., 2015 and Singh and Singh, 2018). Application of organic material along with inorganic fertilizers into the soils leads to increase in productivity of the cropping system enhance the use efficiency of fertilizer input and sustain the soil health for longer period (Jat et al., 2015 and Tambe et al*.,* 2019). Fertilizer is one of the costliest inputs of crop production, it is therefore, very important to find out the way of economic use of fertilizer (Dhakal et al*.,* 2016 and Kumar et al., 2020).

Best management practices are approaches based on experiments made in different parts of the country that, if followed, should allowed the farmers to meet the optimum production to achieve the desired objectives for crop, nutrients, water and soils, (Ramesh et al., 2017). Inclusion of legumes in the cropping system has been known since times immemorial. Legume is a natural mini-nitrogen manufacturing factory in the field and the farmers by growing these crops can play a vital role in increasing indigenous nitrogen production. Legume help in solubilizing insoluble P in soil, improving the soil physical environment, increasing soil microbial activity, and restoring organic matter, and also has smothering effect on weed. The carryover of N derived from legume grown, either in crop sequence or in intercropping system for succeeding crops, is also important. In a country like India, where the average consumption of plant nutrients from chemical fertilizers on national basis is very low, the scope for exploiting direct and residual fertility due to legumes has obviously a great potential. This article deals with the beneficial effect of important legumes on increasing productivity and nutrient use-efficiency in various systems (Gosh et al., 2007).

Hence, the present study was planned and carried out to explore alternative of rice wheat system, appropriate nutrient management for soybean – wheat system and its impact on productivity and soil health.

## 2. Materials and Methods

### *2.1. Experimental site*

Field experiment was conducted at same plot of Tulsi Krishi Vigyan Kendra, Ganivan, Chitrakoot, Uttar Pradesh state, India during *kharif* (Mid-June to 1$^{st}$ week of November) and *rabi* (from Last week of November to Last week of March) in 2008-09 and 2009-10 under the agro-climatic condition of Bundelkhand region of Uttar Pradesh, India (25°10' N latitude and 82°42' E longitude and an altitude of 132.98 meter above mean sea level). The experiment site is located in semi-arid and subtropical climate with 850 mm mean annual rainfall. In this region, the onset of monsoon rains occurs in the fourth week of June. The total rainfall received 624.5 mm and 654.5 mm in the year 2008-09 and 2009-10, respectively. Most of this rainfall was received during July and August (372.50 and 363.50 mm) in two consecutive years. Mean monthly maximum temperature was 48.8 °C in May during 2008-09 and 40.6 °C in April 2009-10 however, minimum temperature was recorded 6.7 °C and 8.8 °C in January during two consecutive years. The soil is sandy loam (sand-28%, silt-34% and clay – 38%) having 0.31% organic carbon with a pH of 7.34. The available NPK in the soil were 125.09, 15.96 and 328.22 kg ha$^{-1}$, which showed rich in potassium, medium in phosphorus and poor in nitrogen.

### *2.2. Experiment design*

Eighteen treatments comprised $T_1$: control, $T_2$: 50% NPK (soybean -S) – 100% NPK (wheat -W), $T_3$: 75% NPK (S) – 75% NPK (W), $T_4$: 100% NPK (S) – 50% NPK (W), $T_5$: 100% NPK (S) – 75% NPK (W), $T_6$: 100% NPK (S) – 100% NPK (W), $T_7$: 50% NPK + FYM 10 t ha$^{-1}$ (S) – 50% NPK (W), $T_8$: 50% NPK + vermicompost 5 t ha$^{-1}$ (S) – 50% NPK (W), $T_9$: 50% NPK + CPP 3.75 kg ha$^{-1}$ (S) – 50% NPK (W), $T_{10}$: 50% NPK + FYM 10 t ha$^{-1}$ (S) – 100% NPK (W), $T_{11}$: 50% NPK + vermicompost 5 t ha$^{-1}$ (S) – 100% NPK (W), $T_{12}$: 50% NPK + CPP 3.75 kg ha$^{-1}$ (S) – 100% NPK (W), $T_{13}$: 75% NPK + FYM 5t ha$^{-1}$ (S) – 75% NPK (W), $T_{14}$: 75% NPK + vermicompost 2.5 t ha$^{-1}$ (S) – 75% NPK (W), $T_{15}$: 75% NPK + CPP

1.875 kg ha-$^{1}$ (S) – 75% NPK (W), $T_{16}$: 100% NPK + FYM 5 t ha-$^{1}$ (S) – 100% NPK (W), $T_{17}$: 100% NPK + vermicompost 2.5 t ha-$^{1}$ (S) – 100% NPK (W), $T_{18}$: 100% NPK + CPP 1.875 kg ha-$^{1}$ (S) – 100% NPK (W) and tested in Randomized Block Design with 3 replications. The recommended dose of 100% NPK to soybean (S) and wheat (W) were 20: 80: 40 and 120: 60: 40 kg N: $P_2O_5$ : $K_2$ O/ha, respectively. In soybean, all amount of NPK were applied as basal in furrows before planting. While, in wheat 1/3 N + full amount of P and K were given as basal in furrows before sowing. The remaining 2/3 N was applied in two equal split doses after first and second irrigation as top dressing. Urea (46% N), DAP (18%N, 46% $P_2O_5$) and Muriate of Potash ($K_2O$) were used to supply N,P,K, respectively. The amount of N was adjusted with DAP and then urea as per treatments. The FYM (0.43 : 0.29 : 0.73% N:P:K), vermicompost (1.36 : 0.23 : 0.82% N:P:K) and cow pat pit (1.68 : 0.31 : 0.85% N:P:K) were used as organic manures as per treatments.

*2.3. Crop culture*

The soybean was sown at a distance of 45 cm and and wheat at a distance of 22.5 cm. The plant distance of soybean was maintained at 10 cm after one week of emergence. Seeds were treated with appropriate fungicides and *Rhyzobium* culture before sowing. Sowing of soybean was done on 14$^{th}$ and 15$^{th}$ July and harvested on 2$^{nd}$ and 4$^{th}$ Nov. in 2008 and 2009, respectively. While, wheat was sown on 29$^{th}$ and 28$^{th}$ Nov. and harvested on 25$^{th}$ and 26$^{th}$ March in 2009 and 2010, respectively. All necessary plant protection, irrigation and other management practices were followed during crop growth. Wheat was given 3 irrigations on 18$^{th}$ Dec., 12$^{th}$ Jan.,9$^{th}$ Feb. during 2008-09 and 18$^{th}$ Dec., 10$^{th}$ Jan., 10$^{th}$ Feb. during 2009-10. Soybean crop was hand weeded once, 1 month after sowing. No incidence of serious insect or diseases was observed. Crops were harvested manually by sickle from ground level and the total above ground biomass was removed from each plot and seed and straw yield were recorded as per treatments.

The available nitrogen, phosphorus and potassium content in seed and straw were analyzed by modified Kjeldahl method (Bremner and Mulvaney, 1982), Vanadomolybdophosphoric yellow colour method (Koenig and Johnson, 1942) and Ammonium acetate method (Jackson, 1967) and their uptake were calculated in kg ha$^{-1}$ according to biological yield of respective plots. However, nitrogen, phosphorus and potassium in soil were analyzed by Kjeldahl digestion and distillation method (Jackson, 1971), Olsen's method (Olsen et al., 1954) and Ammonium acetate method (Jackson, 1967), respectively.

## 3. Results and Discussion

*3.1. Effect of INM on soybean*

*3.1.1. Growth and nodulation*

Growth parameters like plant height, number of trifoliate leaves and plant dry matter 83.30 cm, 41.65 and 35.10 respectively, were recorded significantly higher with the application of 100% NPK through fertilizer +FYM @ 5 t ha$^{-1}$. At 60 days stage during study (Table 1). It might be due to balance dose of fertilizers and slow element releasing tendency of FYM. Under this treatment, crop plants avail the nutrition for longer period therefore; it promotes more growth and development of soybean crop. The application of FYM might have enhanced microbial activities at root zone of soybean crop, which may help for nutrient transformation. Nagar et al. (2016) also experienced similar observations in their experiments. Nodules count (71) and nodules dry weight (0.60 g) were also recorded significantly higher under same treatment combination at 60-days stage during both the year. It might be due to availability of abundant organic matter and effective microbial activities because of sufficient supply of feeding material for Rhizobium bacteria in the form of humus. Similar findings have also supported by Dhakal et al. (2016) and Chaudhary et al. (2019).

*3.1.2. Yield and harvest index*

Seed yield of soybean was recorded significantly higher (pooled value 2.52 t ha$^{-1}$) under 100% NPK+FYM @ 5 t ha$^{-1}$ ($T_{16}$ ) over rest of the treatments, except $T_{13}$ (75% NPK + FYM @ 5 t ha$^{-1}$), $T_{14}$ (75% NPK+vermicompost @ 2.5 t ha$^{-1}$), $T_{17}$ (100% NPK + vermicompost @ 2.5 t ha$^{-1}$) and $T_{18}$ (100% NPK+CPP @ 1.875 kg ha$^{-1}$) during experiment which showed statistically at par with $T_{16}$ (Table 1). Similarly, straw yield of soybean recorded significantly greater (pooled value 2.54 t ha$^{-1}$) under $T_{16}$ treatment over rest of the treatments except $T_{17}$ during both the year. Obviously maximum grain yield of soybean could be due to higher values of yield components. Optimum quantity of NPK and organic manures promote the bio- physical activities of crop plants that convert proteins and carbohydrates in the form of grains. These biophysical and biological interactions might have led to additional pod and seed setting. Moreover, the synergistic effect of NPK and FYM / vermicompost promotes the growth parameters and ultimately gave higher straw yield. Highest grain and stover yield of soybean with INM was also reported by Das et al. (2015) and Kumari et al. (2017). The harvest Index of soybean was found with grain and straw yields to higher pooled values (49.80%) in experiment with 100% NPK+FYM @ 5 t ha$^{-1}$ These findings are in agreement with those of Samant et al.(2016) and Antil and Devraj (2019).

*3.1.3. Nutrient uptake*

Nutrient uptake of nitrogen in soybean crop was recorded significantly higher (216.35 kg ha$^{-1}$) under 100% NPK+FYM @ 5 t ha$^{-1}$ ($T_{16}$) over rest of the treatments during both the years. However, significantly greater uptake of phosphorous (34.70 kg ha$^{-1}$) and potassium (89.50 kg ha$^{-1}$) by soybean was found under same treatment combination over other treatments except $T_{17}$ (100% NPK+vermicompost @ 2.5 t ha$^{-1}$), which was statistically at par with treatment $T_{16}$. It might be due to addition of FYM, which played important role in solublization of insoluble phosphorus and potash, led

Table 1: Effect of INM on growth parameters, Yields, harvest index and Nutrient uptake of soybean during 2008 and 2009 (Pooled Data)

| Treatment detail Soybean - Wheat | Plant height (cm) 60 DAS | Leaves $Plant^{-1}$ 60DAS | Plant dry matter) 60DAS | Nodules $plant^{-1}$ 60DAS | Nodules dry weight (g) 60 DAS | Yields (t $ha^{-1}$) | | Harvest index | Nutrient uptake (kg $ha^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Grain | Stover | | Nitrogen | Phosphorous | Potash |
| $T_1$ | 49.65 | 19.20 | 14.40 | 14.50 | 0.18 | 0.71 | 0.86 | 44.91 | 62.15 | 13.80 | 33.15 |
| $T_2$ | 62.90 | 26.35 | 19.60 | 26.45 | 0.25 | 1.25 | 1.39 | 47.72 | 112.80 | 22.20 | 57.50 |
| $T_3$ | 71.60 | 30.50 | 24.50 | 34.85 | 0.29 | 1.56 | 1.64 | 48.62 | 149.35 | 26.00 | 67.80 |
| $T_4$ | 74.60 | 35.70 | 30.05 | 54.20 | 0.40 | 1.98 | 2.06 | 49.15 | 184.85 | 28.65 | 80.80 |
| $T_5$ | 74.70 | 35.75 | 30.35 | 54.10 | 0.40 | 1.98 | 2.05 | 49.04 | 185.50 | 29.00 | 80.65 |
| $T_6$ | 74.75 | 36.15 | 30.20 | 55.20 | 0.40 | 1.98 | 2.06 | 49.12 | 186.35 | 29.35 | 81.00 |
| $T_7$ | 73.80 | 36.90 | 26.90 | 45.20 | 0.34 | 1.95 | 2.05 | 48.73 | 181.00 | 29.15 | 80.65 |
| $T_8$ | 72.00 | 35.40 | 24.95 | 41.80 | 0.32 | 1.87 | 1.98 | 48.54 | 173.35 | 28.65 | 79.50 |
| $T_9$ | 64.95 | 30.80 | 22.40 | 40.85 | 0.30 | 1.49 | 1.60 | 47.82 | 139.50 | 24.85 | 64.50 |
| $T_{10}$ | 74.10 | 36.35 | 26.80 | 45.00 | 0.34 | 1.94 | 2.06 | 48.53 | 181.50 | 29.8 | 81.00 |
| $T_{11}$ | 71.30 | 34.40 | 24.75 | 41.80 | 0.32 | 1.90 | 1.97 | 48.83 | 174.50 | 28.65 | 79.65 |
| $T_{12}$ | 65.40 | 31.40 | 22.55 | 41.00 | 0.30 | 1.49 | 1.60 | 48.18 | 139.85 | 25.15 | 63.70 |
| $T_{13}$ | 78.35 | 37.15 | 30.35 | 62.30 | 0.43 | 2.15 | 2.22 | 49.35 | 183.85 | 30.00 | 76.00 |
| $T_{14}$ | 73.15 | 36.20 | 27.95 | 55.40 | 0.41 | 2.10 | 2.17 | 49.21 | 182.15 | 29.15 | 75.00 |
| $T_{15}$ | 71.80 | 34.30 | 25.90 | 51.40 | 0.35 | 1.72 | 1.86 | 47.91 | 169.50 | 27.65 | 70.50 |
| $T_{16}$ | 83.30 | 41.65 | 35.10 | 71.00 | 0.66 | 2.52 | 2.54 | 49.80 | 216.35 | 34.70 | 89.50 |
| $T_{17}$ | 79.75 | 39.30 | 33.50 | 67.75 | 0.65 | 2.44 | 2.51 | 49.25 | 208.35 | 34.15 | 87.50 |
| $T_{18}$ | 75..45 | 37.85 | 32.20 | 65.75 | 0.60 | 2.15 | 2.31 | 48.25 | 189.35 | 30.65 | 82.85 |
| SEm± | 1.12 | 0.98 | 0.14 | 1.75 | 0.46 | 0.13 | 0.08 | 0.21 | 1.455 | 0.325 | 0.78 |
| CD ($p$=0.05) | 3.20 | 2.82 | 0.43 | 4.46 | 0.04 | 0.42 | 0.22 | 0.48 | 4.175 | 0.99 | 2.235 |

DAS – Days after sowing; $T_1$: control, $T_2$: 50% NPK (soybean -S) – 100% NPK (wheat -W); $T_3$: 75% NPK (S) – 75% NPK (W); $T_4$: 100% NPK (S) – 50% NPK (W); $T_5$: 100% NPK (S) – 75% NPK (W); $T_6$: 100% NPK (S) – 100% NPK (W); $T_7$: 50% NPK + FYM 10 t $ha^{-1}$ (S) – 50% NPK (W); $T_8$: 50% NPK + vermicompost 5 t $ha^{-1}$ (S) – 50% NPK (W); $T_9$: 50% NPK + CPP 3.75 kg $ha^{-1}$ (S) – 50% NPK (W); $T_{10}$: 50% NPK + FYM 10 t $ha^{-1}$ (S) – 100% NPK (W); $T_{11}$: 50% NPK + vermicompost 5 t $ha^{-1}$ (S) – 100% NPK (W); $T_{12}$: 50% NPK + CPP 3.75 kg $ha^{-1}$ (S) – 100% NPK (W); $T_{13}$: 75% NPK + FYM 5t $ha^{-1}$ (S) – 75% NPK (W); $T_{14}$: 75% NPK + vermicompost 2.5 t $ha^{-1}$ (S) – 75% NPK (W); $T_{15}$: 75% NPK + CPP 1.875 kg $ha^{-1}$ (S) – 75% NPK (W); $T_{16}$: 100% NPK + FYM 5 t $ha^{-1}$ (S) – 100% NPK (W); $T_{17}$: 100% NPK + vermicompost 2.5 t $ha^{-1}$ (S) – 100% NPK (W); $T_{18}$: 100% NPK + CPP 1.875 kg $ha^{-1}$ (S) – 100% NPK

to higher availability of plant nutrients. The availability of nitrogen and phosphorus increased by addition of FYM thus total uptake of NPK increased. Further integrated fertilizer management ensured higher absorption of NPK because of increased cation exchange capacity in roots. Mohanty et al. (2012), Bandopadhyay et al. (2016), Kumari et al (2017) and Sharma et al. (2019) also reported similar findings. (Table 2).

### *3.1.4. Soil nutrient balance*

The available nitrogen, phosphorus and potassium in soil at initial stage of experiment did not vary statistically in all the experimental plots. However, after harvest of crop, addition of 100% NPK+FYM @ 5 t $ha^{-1}$ ($T_{16}$) recorded significantly higher accumulation of nitrogen (157.15 kg $ha^{-1}$) and Phosphorous (21.85 kg $ha^{-1}$) over rest of the treatments. (Table 2). It might be due to higher nitrogen supply through fertilizer and farmyard manure to soybean crop. *Rhizobium* bacteria present in the roots of soybean crop have played vital role for nitrogen fixation from the atmosphere. Active microbes present inside the nodules promote the maximum accumulation of nitrogen in the soil. While maximum accumulation of potassium (340.60 kg $ha^{-1}$) was with 100% NPK through fertilizer and vermicompost @ 2.5 t $ha^{-1}$. This could be ascribed to higher content of P and K in vermicompost, which provided suitable condition for better activity of microbes, which helps in the conversion of insoluble potash into soluble form in the soil.

Table 2: Effect of integrated nutrient management on available NPK in the soil after soybean (Pooled data of 2008 and 2009)

| Treatment detail Soybean- Wheat | Nitrogen | | Phosphorus | | Potash | |
|---|---|---|---|---|---|---|
| | B.S. | A.H. | B.S. | A.H. | B.S. | A.H. |
| $T_1$ | 62.95 | 98.70 | 10.25 | 14.05 | 238.05 | 223.10 |
| $T_2$ | 89.05 | 123.10 | 17.00 | 16.50 | 252.00 | 254.75 |
| $T_3$ | 82.65 | 131.05 | 15.00 | 16.15 | 259.90 | 267.65 |
| $T_4$ | 75.50 | 130.35 | 13.50 | 16.80 | 263.85 | 286.65 |
| $T_5$ | 82.85 | 144.20 | 15.15 | 18.10 | 267.20 | 289.50 |
| $T_6$ | 89.70 | 148.30 | 17.25 | 19.90 | 271.65 | 294.00 |
| $T_7$ | 80.00 | 132.95 | 14.50 | 16.20 | 262.45 | 309.00 |
| $T_8$ | 79.65 | 128.40 | 14.35 | 16.40 | 264.30 | 308.95 |
| $T_9$ | 76.60 | 119.05 | 13.65 | 15.75 | 256.45 | 291.20 |
| $T_{10}$ | 94.20 | 148.35 | 18.80 | 20.15 | 286.55 | 329.80 |
| $T_{11}$ | 92.90 | 141.55 | 18.25 | 20.60 | 284.40 | 326.40 |
| $T_{12}$ | 90.45 | 127.45 | 17.55 | 16.40 | 274.15 | 302.50 |
| $T_{13}$ | 85.30 | 145.85 | 16.70 | 17.85 | 272.95 | 305.05 |
| $T_{14}$ | 84.40 | 142.40 | 16.40 | 17.95 | 273.40 | 306.55 |
| $T_{15}$ | 83.35 | 129.90 | 15.50 | 17.80 | 269.60 | 293.50 |
| $T_{16}$ | 90.85 | 157.15 | 18.30 | 21.85 | 291.60 | 338.55 |
| $T_{17}$ | 90.75 | 152.20 | 18.20 | 21.50 | 291.00 | 340.60 |
| $T_{18}$ | 89.75 | 147.95 | 17.40 | 21.40 | 286.50 | 329.25 |
| SEm± | 0.935 | 0.605 | 0.245 | 2.535 | 11.665 | 2.865 |
| CD ($p$=0.05) | 1.905 | 1.755 | 0.7 | 0.27 | NS | 8.175 |

B.S: Before sowing, A.H: After harvest

Das et al. (2015), Samant et al. (2016) and Tambe et al. (2019) also reported similar findings.

### *3.2. Residual effect of INM and direct effect of Inorganic fertilizers on Wheat*

#### *3.2.1. Growth parameters*

Application of 100% NPK through fertilizer to wheat and residual effect of FYM 10 t ha$^{-1}$+50% NPK to soybean ($T_{10}$) recorded significantly pooled data of higher plant height (94.20 cm), leaves per plant (18.80), plant dry matter (3.975 g), total tillers (66.7) and effective tillers (48.50) in experiment (Table 3). The possible reasons of higher growth parameters and total tillers/m row length may be ascribed due to balanced dose of nutrients supply and sufficient accumulation of N element and organic content through FYM that obviously increases vegetative growth of wheat. Balanced application of fertilizers and credited macro and micronutrients through organic manures, used in preceding soybean crop enhanced the root and shoot development. Since adequate supply of N promote the physiological process of growth and development of wheat crop and ultimately gave higher values of growth parameters (Table 4). These results have also reported by Thakur et al. (2011), Usadadiya et al. (2013), Nagar et al. (2016), Vinay Singh (2016) and Parewa et al. (2019).

#### *3.2.2. Yield and harvest index*

Application of 100% NPK to wheat and FYM @ 10 t ha$^{-1}$ + 50% NPK to previous soybean crop ($T_{10}$) recorded significantly higher seed (pooled 4.95 t ha$^{-1}$), straw yield (pooled 4.99 t ha$^{-1}$) and Harvest index (49.75%) of wheat over rest of the treatments except 100% NPK with residual impact of vermicompost @ 5 t ha$^{-1}$ and 50% NPK ($T_{11}$) which was statistically at par with $T_{10}$ in experiment (Table3). Nitrogen is an essential ingredient of balance dose of fertilizer and involved in constituents of amino acids, protein and protoplast. It directly influenced plant growth and development of crop canopy through better utilization of photosynthates (Singh et al.,2018). Moreover, at later stage of growth, more photosynthates are diverted and accumulated in spike that attributed to maximum grain yield. Further optimum dose of phosphorus and potassium played their role for development of vigorous seed and a greater number of seeds in spike. Residual macro and micro element through FYM provided better soil environment and physical condition for better root development, which able to supply addition demand of mineral and water for maximum photosynthesis process. The residual N also helped to sustain

Table 3: Effect of INM on growth parameters, Yields and Nutrient uptake of wheat during 2008-09 and 2009-10. (Pooled data)

| Treatment detail soybean-Wheat | Plant height (cm) | Leaves plant$^{-1}$ (#) | Plant dry matter (g) | Effective tillers meter$^{-1}$ (#) | Total tillers meter$^{-1}$ (#) | Yield (t ha$^{-1}$) | | Harvest index | Nutrient uptake (kg ha$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | At harvest | 60 DAS | 60 DAS | At harvest | At harvest | Grain | Straw | | Nitrogen | Phosphorous | Potash |
| $T_1$ | 62.95 | 10.25 | 1.495 | 28 | 47.05 | 1.52 | 1.57 | 48.97 | 31.95 | 4.45 | 13.30 |
| $T_2$ | 89.05 | 17 | 3.335 | 44.45 | 59.4 | 4.31 | 4.44 | 49.26 | 107.80 | 15.45 | 65.15 |
| $T_3$ | 82.65 | 15 | 2.715 | 39.6 | 56.9 | 3.11 | 3.31 | 48.44 | 67.30 | 12.00 | 43.45 |
| $T_4$ | 75.5 | 13.5 | 2.315 | 35.15 | 54.1 | 2.24 | 2.33 | 49.46 | 56.30 | 7.65 | 27.45 |
| $T_5$ | 82.85 | 15.15 | 2.71 | 40.3 | 57.25 | 3.14 | 3.30 | 48.78 | 70.95 | 12.45 | 45.15 |
| $T_6$ | 89.7 | 17.25 | 3.37 | 44.8 | 59.3 | 4.32 | 45.03 | 48.98 | 109.60 | 16.30 | 68.95 |
| $T_7$ | 80 | 14.5 | 2.66 | 38.45 | 55.55 | 3.17 | 3.49 | 47.80 | 81.95 | 11.30 | 50.45 |
| $T_8$ | 79.65 | 14.35 | 2.605 | 38 | 55.2 | 3.09 | 3.40 | 47.62 | 77.15 | 11.00 | 46.45 |
| $T_9$ | 76.6 | 13.65 | 2.355 | 35.3 | 55.8 | 2.45 | 2.60 | 48.59 | 60.95 | 9.80 | 32.15 |
| $T_{10}$ | 94.2 | 18.8 | 3.975 | 48.85 | 66.7 | 4.95 | 4.99 | 49.75 | 121.15 | 20.15 | 82.80 |
| $T_{11}$ | 92.9 | 18.25 | 3.93 | 47.65 | 66.1 | 4.82 | 4.93 | 49.44 | 115.15 | 19.80 | 79.60 |
| $T_{12}$ | 90.45 | 17.55 | 3.59 | 45.3 | 59.45 | 4.40 | 4.57 | 49.03 | 104.65 | 16.50 | 69.45 |
| $T_{13}$ | 85.3 | 16.7 | 3.155 | 42.15 | 60.15 | 4.02 | 4.44 | 47.76 | 94.80 | 16.00 | 64.30 |
| $T_{14}$ | 84.4 | 16.4 | 3.12 | 41.3 | 59.85 | 3.96 | 4.34 | 47.68 | 94.30 | 15.45 | 61.50 |
| $T_{15}$ | 83.35 | 15.5 | 2.835 | 40.45 | 58.8 | 3.25 | 3.59 | 47.46 | 71.65 | 13.00 | 48.80 |
| $T_{16}$ | 90.85 | 18.3 | 3.535 | 46.3 | 66.75 | 4.52 | 4.62 | 49.44 | 114.45 | 19.15 | 74.80 |
| $T_{17}$ | 90.75 | 18.2 | 3.49 | 46 | 65.5 | 4.44 | 4.55 | 49.35 | 109.65 | 18.00 | 71.95 |
| $T_{18}$ | 89.75 | 17.4 | 3.44 | 45.3 | 63.2 | 4.36 | 4.51 | 49.11 | 107.30 | 16.15 | 68.95 |
| SEm± | 0.935 | 0.245 | 0.035 | 0.6 | 0.735 | 0.26 | 0.22 | 0.32 | 0.585 | 0.375 | 0.615 |
| CD ($p$=0.05) | 1.905 | 0.7 | 0.105 | 1.74 | 2.095 | 0.73 | 0.61 | 0.93 | 1.68 | 1.08 | 1.78 |

yield improvement in wheat and sustained the productivity (Aulakh et al.,2012, Jaga and Sharma, 2015 and Sharma et al., 2018). Mutually all factors maximize the grain yield, straw yield and harvest index. These findings are similar those of Nawale et al. (2018) and Tambe et al. (2019) and Kumar et al. (2020).

### *3.2.3. Nutrient uptake*

Nitrogen, Phosphorous and potassium uptake 121.15, 20.15 and 82.80 kg ha$^{-1}$ respectively, of wheat were found significantly greater with 100% NPK + residual impact of FYM @ 10 t ha$^{-1}$ and 50 % NPK ($T_{10}$) over rest of the treatments. (Table 3). It might be due to balanced application of NPK in available form to wheat with residual response of organic manures and inorganic N & P. Consequently, higher microbial activity with the presence of organic matter, which ensured higher availability of NPK thus it, increased root cation exchange capacity. Jointly these owing to increase supply of nutrient to the crop, as well as reduced the loss of organically supplied nutrients. Dwivedi et al. (2016), Singh and Patra (2017), Nawale et al. (2018) and Bairwa et al. (2019) also reported similar findings.

### *3.2.4. Soil fertility status*

The pooled data of available Nitrogen, Phosphorous and Potassium 162.20, 32.10 and 344.80 kg ha$^{-1}$ respectively, were recorded significantly higher under 100% NPK through fertilizer and residual effect of FYM @ 10 t ha$^{-1}$+50% NPK ($T_{10}$). (Table 4). It might be due to accumulation of residual nitrogen through FYM and the increase C: N ratio in the soil. The primary effect of N fertilizer is to increase vegetative production, which ultimately added in the soil in the form of leaves and roots for recycling back in the soil system. The increased available P status may be ascribed due to mineralization of organic sources and solubilization by microbes from native source, which probably increased the availability of P in the soil. These eco-friendly microbes enhanced accumulation of phosphorus in available form in the soil. Similar results had also reported

Table 4: Effect of Integrated Nutrient Management on Available NPK in the soil and Fertility balance

| Treatment detail soybean Wheat | Available NPK (kgha$^{-1}$) before Ist sequence | | | Available NPK (kg ha$^{-1}$) after sequence (Pooled data of 2008 and 2009) | | | Fertility balance (kg ha$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | P | K | N | P | K | N | P | K |
| $T_1$ | 108.4 | 15.9 | 255.0 | 69.7 | 11.4 | 208.3 | - 38.6 | - 4.4 | - 46.7 |
| $T_2$ | 108.0 | 15.9 | 255.3 | 129.8 | 17.9 | 243.7 | + 21.8 | + 2.1 | - 11.6 |
| $T_3$ | 104.2 | 15.8 | 257.0 | 125.2 | 16.5 | 263.9 | + 21.0 | + 0.7 | + 6.8 |
| $T_4$ | 102.3 | 15.9 | 257.7 | 100.4 | 17.6 | 189.2 | - 1.9 | + 1.7 | + 16.8 |
| $T_5$ | 107.6 | 15.8 | 258.2 | 135.7 | 21.9 | 283.2 | + 28.1 | + 6.1 | + 25.3 |
| $T_6$ | 110.7 | 15.9 | 257.2 | 151.7 | 26.8 | 298.8 | + 41.0 | + 10.8 | + 41.5 |
| $T_7$ | 109.1 | 15.8 | 256.9 | 112.3 | 16.5 | 269.2 | + 3.1 | + 0.7 | + 13.0 |
| $T_8$ | 104.2 | 15.8 | 256.0 | 107.2 | 17.2 | 273.9 | + 2.9 | + 1.4 | + 17.9 |
| $T_9$ | 107.7 | 15.8 | 254.0 | 103.2 | 14.9 | 259.1 | - 4.5 | - 0.8 | + 5.1 |
| $T_{10}$ | 104.6 | 15.8 | 256.8 | 160.9 | 28.3 | 338.3 | + 56.3 | + 12.4 | + 81.1 |
| $T_{11}$ | 108.2 | 15.9 | 256.5 | 148.2 | 29.5 | 333.1 | + 39.9 | + 13.6 | + 76.5 |
| $T_{12}$ | 107.2 | 16.0 | 257.6 | 131.3 | 18.6 | 305.6 | + 23.9 | + 2.6 | + 48.1 |
| $T_{13}$ | 106.2 | 15.8 | 256.3 | 132.2 | 21.7 | 302.7 | + 25.9 | + 5.9 | + 46.4 |
| $T_{14}$ | 103.7 | 15.9 | 256.6 | 126.7 | 21.8 | 302.7 | + 23.0 | + 5.9 | + 46.1 |
| $T_{15}$ | 106.4 | 15.9 | 258.1 | 113.5 | 20.4 | 289.1 | + 7.2 | + 3.9 | + 31.1 |
| $T_{16}$ | 105.2 | 15.9 | 258.2 | 162.2 | 32.1 | 344.8 | + 56.9 | + 16.2 | + 87.6 |
| $T_{17}$ | 108.4 | 15.8 | 257.6 | 155.0 | 31.8 | 344.3 | + 46.6 | + 16.1 | + 86.7 |
| $T_{18}$ | 105.3 | 15.8 | 256.5 | 149.7 | 31.0 | 331.5 | + 44.4 | + 15.2 | + 75.1 |
| SEm± | 1.32 | 0.65 | 1.95 | 0.66 | 0.13 | 1.34 | - | - | - |
| CD ($p$=0.05) | NS | NS | NS | 1.89 | 0.38 | 3.85 | - | - | |

by Samant and Patra (2016) and Timsina (2018). Higher value of organic carbon and humus in FYM may generate favorable condition for root and soil friendly microbes to accretion more potassium in available form. These microbes also help some amount of potassium to form available condition in the soil. The application of vermicompost may be attributed due to dissolving action of certain organic acids produced during the decomposition of organic manures and higher capacity of these to hold K in available form. Similar findings have been reported earlier by Dwivedi et al. (2016), Kumari et al. (2017) and Singh et al. (2018).

### 3.2.5. *Fertility balance*

Fertility balance in term of net additional increased quantity of available Nitrogen (+56.9 kg), Phosphorous (+ 16.2 kg) and Potassium (+ 87.60 kg) in the soil after completion of two year sequence of soybean – wheat was recorded maximum and positive balance under treatment 100% NPK through fertilizer+5 t FYM ha$^{-1}$ in soybean crop and 100% NPK to wheat crop ($T_{16}$) followed by 100% NPK through fertilizer+ vermicompost @ 2.5 t ha$^{-1}$ to soybean crop and 100% NPK to wheat crop ($T_{17}$) (Table 4). It might be due to application of both organic and inorganic sources of nutrients in balance amount to the crops of sequence, which accumulated higher NPK in the soil than consumption. Further, addition of bio-mass in the form of leaves, roots and nodules of soybean responded better accumulation of both nutrients in the soil. Jointly, these responded for higher fertility balance. These findings have also similar to Jat et al. (2015), Bandopadhyay et al. (2016), Dhakal et al. (2016), Kumari et al. (2017) and Chaudhary et al (2019).

## 4. Conclusion

A combination of organic and inorganic fertilizers to soybean - wheat system was found best where growth, yield, nutrient uptake and soil fertility parameters were obtained ( yield 2.52 and 4.95 t ha$^{-1}$, Nutrient uptake of NPK 216.35,34.7, 89.50 and 121.15, 20.15, 82.80 kg ha$^{-1}$, Soil fertility balance of NPK 157.15, 21.85, 340.60 and 162.20, 32.10, 344.80 kg ha$^{-1}$ in soybean and wheat, respectively.) greater under 100% NPK to wheat with residual effect of FYM 10 t ha$^{-1}$+50% NPK to soybean during two consecutive years.

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