

## Review Article

# Impact of Bio-stimulants and Integrated Nutrient Management sustainable Wheat production: An overview

### Abstract

The adequate and balanced supply of plant nutrients is of critical importance in improving the productivity of wheat crop. Due to prohibitive cost of chemical fertilizers, Indian farmers, mostly marginal and small, do not supply the recommended doses of nutrients to these energy rich crops, indigenously available organic sources of nutrients have been recorded to enhance the efficiency and reduce the requirement of chemical fertilizers. The nutrients (N, P, K and Zn) can be supplied through fertilizers, organic manures, bio-fertilizers, bio-stimulants and their combined applications under integrated nutrient management. Wheat varieties differ in their phenology, requirement of thermal and photoperiod units and growth habits which cumulatively determine the varietal adaptation at different locations and sowing times. Therefore, comparative evaluation of varieties suitable for early, normal and late sown conditions is warranted to identify the growth patterns, physiological traits and yield attributes that will favourably influence the grain yield and biomass in wheat under normal and late sown conditions. This review examines response of wheat varieties to integrated nutrient management practices in wheat crop sown under normal and late planting conditions.

### INTRODUCTION

“Wheat (*Triticum aestivum* L.) is the world's principal and commercially important food crop. It belongs to the grass family *Poaceae*. Global wheat consumption has increased in the past four decades to around 781 million tonnes (mt) annually and accounts for approximately 25 percent of worldwide protein supply. In India (2022-23), the area under wheat production is 30.46 million hectares (mha) with the production of 12.18 mt. The area under wheat cultivation in Haryana (2021-22) is 2364.14 ha with the production of 12 mt (India stat 2021-2022).

Wheat varieties differ in their phenology, requirement of thermal and photoperiod units and growth habits which cumulatively determine the varietal adaptation at different locations and sowing times. Therefore, comparative evaluation of varieties suitable for early, normal and late sown conditions is warranted to identify the growth patterns, physiological traits and yield attributes that will favorably influence the grain yield and biomass in wheat under normal and late sown conditions. The grain and straw yield in wheat is determined by the genotype of the varieties and the supply of nutrients. The nutrients (N, P, K and Zn) can be supplied through fertilizers, organic manures, bio-fertilizers, bio-stimulants and their combined applications under integrated nutrient management. Several workers have reported beneficial effects of integrated nutrient management (Sharma *et al.* 2020). However, the efficacy of integrated nutrient management depends upon the proportion

of each component of inorganic (fertilizers for macro and micro-nutrients) and organic sources like vermin-compost of nutrient supply and their doses as well as time and method of application. New range of bio-stimulants such as Hairamine (protein hydrolysate from human hair), seaweed extract, humic acid etc. have been developed and are being evaluated for their efficacy and response for yield improvement. However, the available information is scanty and more studies are needed.

## EFFECT OF NPK

The inorganic fertilizers are applied to fulfill the plant requirement for nitrogen, phosphorus, potassium and other micronutrients, but excessive use of chemical fertilizers reduces soil fertility by affecting the soil's physical and chemical properties. Therefore, it is necessary to balance this negative effect of inorganic fertilizers with the use of organic amendments and bio-fertilizers.

Cui *et al.* 2023 conducted "a field experiment to study the effects of nitrogen form on N utilization, yield and quality of two wheat varieties with different gluten characteristics. The results indicated that combined application of urea and nitrate nitrogen could synergistically improve quality and nitrogen use efficiency while maintaining yield, which is important for the rational application of nitrogen fertilizer and achieving stable yield, high quality and efficient production of wheat".

Yang *et al.* 2023 conducted a field experiment to study the effect of nitrogen management on wheat yield, water and nitrogen utilization and economic benefits under ridge-furrow cropping system with supplementary irrigation. The results showed that the ridge-furrow system significantly increased the soil moisture content and improved the water productivity and grain yield of wheat".

Akram *et al.* 2022 conducted "a field experiment to study the effect of phosphorus and sulphur on yield and economics of wheat. The results showed that the application of phosphorus at 80 kg/ha + Sulphur at 40 kg/ha was recorded significantly higher plant height (96.47 cm), number of tillers/hill (10.47), plant dry weight (18.54 g/plant), grains/spike (47.36), test weight (38.59 g), grain yield (6.25 t/ha), straw yield (9.54 t/ha) and harvest index (39.6). Higher gross returns (₹ 99,187/ha), net returns (₹ 67,049 ha<sup>-1</sup>) and benefit cost ratio (2.08) was also obtained with this combination.

Qazizadah *et al.* 2022 conducted a field experiment to study the effect of nitrogen levels on the performance of wheat varieties under saline water irrigation in semi-arid regions. The results showed that incremental N levels significantly increased LAI and number of grains/spike up to 150 kg N/ha but plant height, dry matter accumulation, number of tillers/meter row length, number of effective tillers/meter row length and grain yield were at par with 200 kg N/ha.

Kumar *et al.* 2022 conducted a field experiment to study nitrogen management in late sown wheat. The results indicated that application of 50 percent RDN at sowing + 3 percent urea foliar application at tillering and earing recorded 41.8, 52.6 and 30.6 per cent higher grain yield than other treatments.

Dhaker *et al.* 2022 concluded from their field experiment to study the effect of nutrient management on growth and productivity of wheat grown under rice-wheat based cropping system in South-eastern Rajasthan. The results indicated that the application of 150 percent RDF registered the maximum growth parameters viz., number of tillers/meter row length, CGR and plant height at different growth stages and grain, straw and biological yields. The maximum net return was also obtained under the application of 150 per cent RDF (₹ 106464/ha), however, 125 percent RDF (₹ 103460/ha) and RDF + FYM (₹ 9907/ha) as well as RDF + Zn + S (₹ 99155/ha) were found at par with 150 percent RDF.

Assefa *et al.* 2021 conducted field experiment to study the effects of phosphorus and sulfur on yield and nutrient uptake of wheat on vertisols, North Central Ethiopia. This study revealed that combination of 22 P and 15 S kg/ha produced the highest MMR (54.9 percent).

Klikocka *et al.* 2018 conducted a field experiment to study the response of spring wheat to NPK and S fertilization. The experiment showed a positive response of spring wheat to N and S fertilization. The highest grain yield was found after application of 80 kg N/ha and addition of 50 kg S/ha (5.43 t/ha). The described combination resulted in beneficial content of P - 4.267, K - 4.533, Mg - 1.567, Ca - 0.433 g/kg and uptake of macro-elements by grain dry mass (P-20.48, K-21.79, Mg-7.52, Ca-2.08 kg/ha).

Laghari *et al.* 2016 conducted a field experiment to study the effect of NPK and Boron on growth and yield of wheat variety TJ-83. The result indicated that maximum plant height (86.7 cm), number of tillers (418 m<sup>-2</sup>), spike length (11.6 cm), grains/spike (51.0), grain weight/plant (7.9 g), seed index (41.7 g), biological yield (9131.7 kg/ha), grain yield (2105 kg/ha) and harvest index (42.5 percent) were obtained with the application of NPK-120-60-60 kg/ha + B2 percent at tillering phase.

Khan *et al.* 2012 conducted a field experiment to study the effect of different rates of NPK on the yield contributing traits and economics of wheat in Rod Kohi area of Dera Ismail division, Pakistan. The data revealed that the yield parameters increased with an increase in each fertilizer nutrient (N, P and K) during both the years. Best fertilizer economy (maximum benefit/ha) was received from the application of 80-40-20 kg/ha N: P: K. Greater values of all parameters were found during 2007-08 as compared to 2006-07, which may be attributed to residual effect of NPK application accompanied by favorable climatic condition during second year of growing wheat crop.

Malghaniet al. 2010 conducted a field experiment to study the response of growth and yield of wheat to NPK fertilizer. The result revealed that highest grain yield of 5168 kg ha<sup>-1</sup> was recorded with the application of 175-150-125 NPK kg ha<sup>-1</sup>. The increase in yield was 51.58 per cent higher as compared to control (2502 kg/ha), where no fertilizer was used”.

Warraich et al. 2002 conducted a field experiment to study the effect of nitrogen on grain quality and vigour in wheat. The results proved that seeds obtained from 120 kg N/ha treatment showed more vigour during electrical conductivity test as compared to 0, 60 and 180 kg N/ha.

## **EFFECT OF BIO-FERTILIZERS**

Bio-fertilizers are considered as an important constituent of sustainable agriculture. The crop productivity and profitability can be enhanced by inoculating the pulse crops with *Rhizobium* culture and phosphorus solubilizing bacteria (PSB). From agricultural point of view, *Rhizobium* are pivotal soil bacteria having the ability to form root nodules and stem nodules in some cases, in legumes to fix atmospheric nitrogen. Bio-fertilizers are carrier-based preparations containing beneficial microorganisms in a viable state intended for seed or soil application to improve soil fertility and plant growth. Bio-fertilizers increase the number and biological activity of beneficial microorganisms in the rhizosphere. They improve soil fertility by fastening the atmospheric nitrogen, solubilizing insoluble soil phosphates, and discharging plant growth substances in the soil. Bio-fertilizers are cost-effective, eco-friendly and renewable sources of plant nutrition. The crop productivity and profitability can be improved by the inoculation of pulse crops with phosphorus solubilizing bacteria (PSB) and *Rhizobium* (Bajracharya et al. 2009).

Pawar and Suryawanshi 2022 conducted an experiment to study the impact of bio-fertilizer on paddy (*Oryza sativa* L.) cultivar Jaya. The results suggest that bio-fertilizers from microorganisms can replace chemical fertilizers to increase crop production.

Amrutha et al. 2022 conducted an experiment to study the influence of bio-fertilizers on growth and yield of rice (*Oryza sativa* L.). From the data collected, it was observed that the combined application of POP, KAU + *Azolla* + AMF had the highest number of grains/panicle (155.37), 1000-grain weight (24.16 g) and grain yield (3718.52 kg/ha) when compared to the control.

Kekatpure and Chaturvedi 2021 conducted an experiment entitled growth and yield response of wheat in relation to the use of varieties and bio-fertilizer. On the basis of data collected, highest plant height (83.66 cm), number of tillers per meter row length (66.47) at 90 DAS while, number of spikes/plant (21.00), spike length (13.53 cm), number of grains/spike (29.40), test weight (41.36 g), grain yield (38.95 q/ha), stover yield (68.21 q/ha) were recorded under the wheat variety GW-322 sown with bio-fertilizer of *Azotobacter* at 10 ml/kg seed inoculation + 500 ml/acre foliar application.

Achari *et al.* 2021 conducted an experiment to study the effect of bio-fertilizers and nitrogen levels on growth and yield of wheat (*Triticum aestivum* L.). The results indicate that the application of *Azotobacter* + *Azospirillum* + 140 kg/ha N was recorded significantly higher plant height (86.07 cm), number of tillers/plant (6.34), dry weight (19.58 g/plant), number of effective tillers/m<sup>2</sup> (296.16), length of spike (11.25 cm), test weight (46.93 g), number of grains/spike (58.11), grain yield (5.63 t/ha) and straw yield (13.20 t/ha), whereas harvest index (33.1 percent) was recorded maximum with *Azotobacter* + 120 kg/ha N.

Aechraet *et al.* 2020 conducted an experiment to study the effect of bio-fertilizers and split application of vermi-compost on productivity and profitability of wheat (*Triticum aestivum* L.) crop in clay loam soils. Two years pooled data indicated that growth attributes (plant height), yield attributing traits (total tillers, effective tillers and test weight), yields viz., grain, straw and biological in wheat differs significantly, in both bio-fertilizers and vermi-compost treatments and were maximum with the B5 (*Azotobacter* + PSB + KMB + ZnSB) and V3 (50 per cent at sowing + 50 per cent at tillering) as compared to control. The highest net return and B:C ratio was also obtained with this combination.

Thejshet *et al.* 2019 conducted “a field experiment titled studies on growth, yield and economics of rice (*Oryza sativa* L.) var. Pusa Basmati-1 as influenced by bio-fertilizers. The experimental results revealed that the application of RDF + PSB at 2 kg/ha + *Azospirillum* at 2 kg/ha has recorded highest number of grains/panicle (151.93) and number of panicles/hill (21.8).

Devaet *et al.* 2019 conducted an experiment to study the effect of liquid bio-fertilizer on yield and economics of rice. The results indicated that application of bio-fertilizers improved yield and B:C ratio of rice.

Ali *et al.* 2019 conducted an experiment to study the effect of bio-fertilizer on yield and yield components of wheat under Iraq conditions. From this experiment, researchers concluded that the application of bio-fertilizer resulted in a positive effect on nutrients balance in the soil at the end of season regardless of type of bio-fertilizers as indicated by the increase in levels of NH<sub>4</sub>, NO<sub>3</sub>, P and K”.

Nagwaet *et al.* 2019 conducted “an experiment to study the influence of some bio-fertilizer on wheat plants grown under graded level of nitrogen fertilization. According to the obtained results of this experiment, application of bacterial strains *Azospirillum* + *Azotobacter* in present of 50 percent (nitrogen of recommended dose) could save 50 per cent of the recommended dose of mineral N and could increase growth and yield to an acceptable level, so it could be considered as a suitable substitute for chemical nitrogen fertilizer in organic agricultural systems.

Nguyen *et al.* 2019 conducted an experiment to study the biostimulant effects of *rhizobacteria* on wheat growth and nutrient uptake depend on nitrogen application and plant

development. The results revealed that at 50 N, plant biomass was most significantly increased in roots (up to +45 percent with *Azospirillum brasilense* 65 B) at stem-elongation stage and in the ears (+19-23 percent according to the strains) at flowering stages. Therefore, combining PGPR (Plant growth promoting rhizobacteria) with a proper cultivated system, N rate and plant stage could enhance their biostimulant effects.

Singh *et al.* 2015 conducted an experiment to study the effect of bio-fertilizers on growth, yield and economics of rice (*Oryza sativa* L.). From this experiment, researchers found out that maximum grain yield (65 q/ha) was recorded with 150 kg N + 60 kg P<sub>2</sub>O<sub>5</sub> + 40 kg K<sub>2</sub>O with *Azotobacter* + PSB at 5 kg/ha.

Karmakare *et al.* 2011 conducted a field experiment to study the effect of green manuring and bio-fertilizer on rice production. The results revealed that combined application of 50 percent of recommended dose through chemical fertilizers and 25 percent N through FYM along with in situ green manuring and blue green algae improved growth and yield attributing characters resulted in an increase in yield of rice variety Lalat (19.3 percent) as compared to that of recommended fertilizer dose increase in nutrient uptake (21.4, 29.0 and 16.9 percent of N, P and K, respectively) and improvement of the soil physico-chemical properties like organic carbon (0.34-0.44 percent), available N (220.3-254.0 kg/ha), P (21.2-25.8 kg/ha) and K status (153.0-159.0 kg/ha) were also recorded. The maximum net returns (22160 kg/ha) and B: C of 2.23 was also noted under the combined nutrient application.

## EFFECT OF BIO-STIMULANTS

Bio-stimulant Hairamin reduces the need of fertilizers and increases plant growth, develops resistance in plants against abiotic stresses. In small concentration, this substance is efficient in favouring good performance of the plants' vital processes and allowing higher yield. In addition, bio-stimulants applied to plants enhance nutrients' efficiency, abiotic stress tolerance and plant quality traits (De Vasconcelos and Chaves (2019)).

Kumar *et al.* 2023 conducted a field experiment to study the genetic variability among winter cereal genotypes for response to protein hydrolysate (PH) for grain yield and its attributes. This study concludes that the foliar application of protein hydrolysate showed significant results on the plant height, spike length and yield of crops. This type of protein hydrolysate having short peptide and free amino acids are accumulated directly by plants and enhance the growth and maintain plant health. The application can be an alternative of chemical-based fertilizers and reduce the environment pollution.

Kumar *et al.* 2022 conducted a field experiment to evaluate the efficacy of protein hydrolysate (Plant Force Advance) based formulation on cotton yield. The study concluded that the foliar application

on of protein hydrolysate along with recommended package of practices in Bt. hybrid cotton have promising results on the yield and growth of cotton under the field conditions.

Popkoet *al.* 2018 conducted “an experiment to study the effect of the new plant growth bio-stimulants based on amino acids on yield and grain quality of winter wheat. Field experiments showed that the application of products based on amino acids influenced the increase of grain yield of winter wheat (5.4 and 11 percent, respectively, for the application of *Amino Primat* at dose 1.0 lha<sup>-1</sup> and *Amino hortat* at dose 1.25 lha<sup>-1</sup>) when compared to the control group without biostimulant”.

Majathoub 2004 conducted “an experiment to study the effect of bio-stimulants on production of wheat (*Triticum aestivum* L.). The results showed that the plants treated with *Vigro* exhibited an increase in the total tillers (21 percent), a greater number of fertile florets per spike. Nevertheless, the economic yield (grain yield) had improved by 8.2 percent.

## **EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON PLANT GROWTH, YIELD ATTRIBUTES AND YIELD OF WHEAT**

Integrated Nutrient Management refers to the conservation of soil fertility and plant nutrients up to an optimum level for sustaining the desired productivity by utilizing all possible sources of organic, inorganic and biological components in an integrated manner. Under integrated nutrient management, the harmful effects of inorganic fertilizers can be balanced with the use of *rhizobium* culture, phosphorus solubilizing bacteria (PSB), bio-fertilizers and vermi-compost.

Jama *et al.* 2023 conducted “a field experiment to study the integrated use of phosphorus fertilizer and farmyard manure improves wheat productivity by improving soil quality and phosphorus availability in calcareous soil under sub-humid conditions. From this experiment, it is concluded that FYM concoction with fertilizer-P not only improved SOM and residual soil, but also enhanced wheat yields with reasonable P efficiency”.

Dhaliwal *et al.* 2023 conducted a field experiment to study the residual effect of organic and inorganic fertilizers on growth, yield and nutrient uptake in wheat under a Basmati rice-wheat cropping system in North-western India. The results concluded that the integrated application of FYM with 75 per cent RDN could be used to sustain wheat productivity and maintain soil fertility which otherwise deteriorates due to the sole application of inorganic fertilizers”.

Tufa 2023 conducted an experiment to study the vermi-compost N, P, S, Zn, B fertilizer levels on maize (*Zea mays* L.) growth, yield component and yield at Guto Gida, Western Ethiopia. From this experiment, it is concluded that the integrated applications of vermi-compost at 5 t/ha and NPSZnB fertilizer at 100 kg/ha increased maize yield by about 10.36 per cent, with a net benefit of 140486.00 ETB/ha and a marginal rate of return of 797.98 percent. As a result, vermi-compost application at 5 t/ha rate with synthetic NPSZnB fertilizer at 100 kg/ha is found suitable for the study area.

Saini *et al.* 2023 conducted an experiment to study the growth and yield attainment of wheat under different levels of vermi-compost, bio-fertilizers and nitrogen. The results indicated that significantly higher growth and yield viz., plant height (85.1, 81.6, 82.5 cm), number of tillers/plant (3.72, 3.56, 3.62), dry matter accumulation at harvest (261.0, 242.5, 249.4 g per meter row length), length of spike (10.9, 10.2, 10.4 cm), number of seeds/spike (40.16, 37.74, 37.93), grain weight/spike (1.52, 1.45, 1.48 g) and test weight (38.54, 37.28, 37.65 g) with individual application of 4 t/ha vermi-compost, *Azotobacter chroococcum* inoculation at 5 ml/kg seed and 100 percent RDN, respectively”.

Messaoudi *et al.* 2023 conducted an experiment for investigating the potassium fertilization effect on morphological and agronomical indicators of Durum wheat under Mediterranean rain-fed conditions. Based on grain yield and evaluated agronomic traits, this research revealed that an applied potassium rate of 100 kg K<sub>2</sub>O/ha is recommended as the most effective dose to maximize durum wheat yield and quality under Algerian sub-humid conditions.

Kantwaet *et al.* conducted an experiment to study the effect of wheat varieties and integrated nutrient management practices on nutrient content, uptake and soil nutrient status. In this study, they observed that among nutrient management practices, nitrogen, phosphorus and potassium content, uptake, grain and straw yield of wheat were significantly higher under application of 100 per cent RDF + *Azotobacter* + PSB. Further, results revealed that different wheat varieties did not bring any significant variation in available nitrogen, phosphorus, potassium, zinc and organic carbon content in soil. Moreover, highest available nitrogen and phosphorus in soil was recorded with the application of 100 per cent RDF + *Azotobacter* + PSB. However, significantly higher organic carbon and zinc content in soil was observed under 50 per cent RDF + 25 per cent N through FYM + *Azotobacter* + PSB + ZnSO<sub>4</sub>.

Patya *et al.* 2022 conducted an experiment to study the effect of integrated nutrient management (INM) on growth parameters and yield of wheat (*Triticum aestivum* L.). The results showed that among various treatments, 100 percent RDF + 25 percent N through vermi-compost + ZnSO<sub>4</sub> at 25 kg ha<sup>-1</sup> proved to be found better with respect to plant height (92.25 cm), dry matter accumulation (274.65 g m<sup>-2</sup>) and number of tillers m<sup>-2</sup> (92.43 m<sup>-2</sup>) at harvest stage in respective years.

Kumar and Niwas 2022 conducted an experiment to study the effect of organic and inorganic fertilizers on growth and yield of wheat (*Triticum aestivum* L.). The results showed that the higher plant population, plant height, dry matter, number of tillers, number of effective tillers, leaf area index, day to flowering, length of ear, number of spike, number of spikelet/year, number of grains/ear, biological yield, grain yield, straw yield, harvest index and B: C ratio were observed with the application of 100 percent NPK + 5 t ha<sup>-1</sup> FYM + 5 t ha<sup>-1</sup> vermi-compost + PSB.

Kumawatet *al.* 2021 conducted a field experiment to study about the effect of fertility levels and liquid bio-fertilizers on growth and yield of wheat. The results showed that significant increase in plant height, total tillers per metre row length, effective tillers per metre row length, test weight, grain; straw and biological yield was observed with the combine application of 100 per cent RDF and *Azotobacter*+PSB”.

Emamu *et al.* 2021 conducted a field experiment entitled the effect of integrated application of vermi-compost and NPS fertilizer on soil physicochemical properties and yield of maize (*Zea mays* L.) crop at Toke Kutayed district, Western Ethiopia. From this experiment, it can be concluded that the application of vermi-compost along with NPS fertilizers improved organic matter and nutrient contents of the soils which in turn increased crop yields. Hence, in order to maintain soil fertility and sustain maize crop production, farmers of the study area and similar agroecologies are advised to make integrated use of vermi-compost at 5 t/ha and NPS inorganic fertilizer at 50 kg/ha tentatively.

Fazily *et al.* 2021 conducted a field experiment entitled effect of integrated nutrient management on growth, yield attributes and yield of wheat. The highest yield attributes and yield of wheat was produced with the application of 100 percent recommended dose of N (RDN) + 25 percent nitrogen through vermi-compost during both the consecutive years, but it did not differ significantly with application of 100 percent RDN. On the basis of two years pooled data, T3 produced 94.96 percent higher number of (*Triticum aestivum* L.). The results of the experiment indicated that combined application of inorganic fertilizer at higher/lower dose along with FYM, bio-fertilizer and sulphur gives significantly higher spikes per metre row length, spike length, number of grains per spike and yield. However, the lowest yield and yield attributes were recorded with the RDF”.

Devi *et al.* 2011 conducted “a field experiment over two years on clay loam soil to assess the effect of integrated nutrient management (INM) practices on growth and yield of wheat (*Triticum aestivum* L.). The results revealed that the application of 100 per cent RDF + vermi-compost at 1 t ha<sup>-1</sup>+PSB and 75 per cent RDF + Vermicompost at 1 t ha<sup>-1</sup>+ PSB produced higher yield attributes and grain yield than the other treatments. The higher yield led to higher NPK uptake by wheat. Further, the available NPK content of soil also increased in above INM treatment over control. The highest benefit: cost ratio (2.73) was obtained from the application of 75 percent RDF + vermi-compost at 1 t ha<sup>-1</sup>+PSB”.

Pandey *et al.* 2009 conducted “a field experiment to find out the effect of integrated nutrient management on productivity of late sown wheat (*Triticum aestivum* L.). The results showed that application of 150 per cent RDF together with 10 tonnes FYM + 25 kg ZnSO<sub>4</sub>/ha although produced maximum grain yield (3.8-3.9 t ha<sup>-1</sup>). However, higher benefit: cost ratio (1.5-1.7) was obtained with 10 t FYM/ha together with RDF only. Addition of 10 t FYM with fertilizer levels significantly increased the nutrient uptake by the crop, improved the organic carbon content, N, P and K status and significantly reduced the bulk density of the soil as compared to chemical fertilizer alone.

Rehman *et al.* 2008 conducted a field experiment entitled 'Organic and inorganic fertilizers increase wheat yield components and biomass under rainfed condition. From the results, it is concluded that 80-60-60 kg NPK/ha and 30 t FYM/ha have produced maximum wheat yield components and biomass under rainfed condition'.

## CONCLUSION

In conclusion, the collective findings from the reviewed studies provide strong evidence in support of integrated nutrient management as a holistic approach for promoting productivity and sustainability of wheat based cropping system. By optimizing the use of organic (vermi-compost, FYM, bio-stimulants, compost *etc.*) and inorganic inputs (macro- and micronutrients containing synthetic chemical fertilizers), farmers can improve soil fertility, increase crop productivity, and mitigate environmental impacts, thereby contributing to the long-term viability of agricultural systems.

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