Journal of Experimental Agriculture International

Volume 46, Issue 7, Page 134-143, 2024; Article no.JEAI.116750
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Impact of Bio-stimulants and Integrated Nutrient Management Sustainable Wheat Production: An Overview

Jag Mohan [a*], Vikas Tomar [a], Sahil [a], Sahil Mittan [a] and Prince [a]

[a] *Maharishi Markandeshwar (Deemed to be) University, Mullana, Ambala, Haryana, India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/jeai/2024/v46i72565

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/116750

Review Article

Received: 08/03/2024
Accepted: 11/05/2024
Published: 07/06/2024

ABSTRACT

A sufficient and well-balanced supply of plant nutrients is essential for increasing wheat crop output. The high cost of chemical fertilisers has prevented Indian farmers, who are primarily marginal and small-scale farmers, from providing these energy-dense crops with the recommended doses of nutrients. Instead, locally available organic sources of nutrients have been shown to increase crop productivity and decrease the need for chemical fertilisers. Under integrated nutrition management, the nutrients (N, P, K, and Zn) can be supplied via fertilisers, organic manures, bio-fertilizers, bio-stimulants, and their combined applications.

Varietal adaptation at various locations and sowing dates is determined by the differences in phenology, growth habits, and requirements for temperature and photoperiod units among wheat varieties. In order to determine the growth patterns, physiological features, and yield attributes that

**Corresponding author: E-mail: jagmohan1610@gmail.com;*

Cite as: *Mohan, Jag, Vikas Tomar, Sahil, Sahil Mittan, and Prince. 2024. "Impact of Bio-Stimulants and Integrated Nutrient Management Sustainable Wheat Production: An Overview". Journal of Experimental Agriculture International 46 (7):134-43. https://doi.org/10.9734/jeai/2024/v46i72565.*

will favourably influence the grain yield and biomass in wheat under normal and late seeded settings, a comparative evaluation of varieties appropriate for early, normal, and late sown conditions is necessary. The reaction of wheat cultivars to integrated nutrition management techniques in wheat crops grown under typical and late planting circumstances is reviewed in this review.

Keywords: Bio-stimulants impact; nutrient management; wheat production; food crop.

1. 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 per cent of worldwide protein supply. In India (2022-23), the area under wheat production is 30.46 million hectares (mha) with the production of 112.18 mt. The area under wheat cultivation in Haryana (2021-22) is 2364.14 ha with the production of 12 mt [1].

Varying wheat varieties have varying phenologies, growth patterns, and requirements for temperature and photoperiod units, all of which affect how well the variety adapts to various environments and sowing times. In order to determine the growth patterns, physiological features, and yield qualities that would positively influence the grain yield and biomass in wheat under normal and late seeded settings, a comparative evaluation of varieties appropriate for early, normal, and late sown conditions is necessary. The genotype of the varieties and the availability of nutrients affect wheat's output of grains and straw. Under integrated nutrition management, the nutrients (N, P, K, and Zn) can be supplied via fertilisers, organic manures, bio-fertilizers, bio-stimulants and their combined applications.

Several workers have reported beneficial effects of integrated nutrient management [2]. However, the amount and dosage of each component of organic (vermi-compost) and inorganic (fertilisers for macro and micronutrients) sources of nutrient delivery, as well as the timing and technique of administration, determine how effective integrated nutrition management is. A new class of bio-stimulants, including humic acid, seaweed extract and Hairamin (a protein hydrolysate from human hair), have been produced and are being tested for yield improvement. Still, there is a dearth of material available, and further research is required.

2. EFFECT OF NPK

In order to provide plants with the nitrogen, phosphorous, potassium, and other micronutrients they need, inorganic fertilisers are applied. However, overuse of chemical fertilisers depletes soil fertility by altering the physical and chemical composition of the soil. Therefore, the usage of organic amendments and bio-fertilizers is required to counteract this detrimental effect of inorganic fertilisers.

Cui et al. [3] carried out a field experiment to investigate how different nitrogen forms affect the yield, quality, and utilisation of nitrogen in two wheat cultivars with distinct gluten properties. The findings showed that applying urea and nitrate nitrogen together could enhance quality and nitrogen use efficiency while preserving yield. This is crucial for applying nitrogen fertiliser sensibly and producing wheat that is high-quality, stable, and produced efficiently.

Yang et al. [4] 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 findings demonstrated that the ridge-furrow technique greatly raised the moisture content of the soil, enhanced wheat grain production, and water productivity.

Akram et al. [5] carried out a field experiment aimed at examining the impact of phosphorus and sulphur on wheat yield and economics. 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) were all significantly higher following application of phosphorus at 80 kg/ha + sulphur at 40 kg/ha. This combination also produced higher net returns (₹67,049 ha^{-1}), benefit cost ratio (2.08), and gross returns (₹ 99,187/ha).

Qazizadah et al. [6] 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. [7] conducted a field experiment to study nitrogen management in late sown wheat. The results indicated that application of 50 per cent RDN at sowing + 3 per cent 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. [8] 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 per cent 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 per cent RDF (₹ 103460/ha) and RDF + FYM (₹ 9907/ha) as well as RDF + Zn + S (₹ 99155/ha) were found at par with 150 per cent RDF.

Assefa et al. [9] 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 per cent).

Klikocka et al. [10] 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).

In order to investigate the impact of NPK and Boron on the growth and yield of the wheat variety TJ-83, Laghari et al. [11] carried out a field experiment. The results showed that applying NPK-120-60-60 kg/ha + B 2 percent during the tillering phase produced the maximum plant height (86.7 cm), number of tillers (418 m-2), 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).

In the Rod Kohi area of Dera Ismail division, Pakistan, Khan et al. [12] carried out a field experiment to investigate the impact of varying amounts of NPK on the yield contributing characteristics and economics of wheat. The information showed that, in both years, the yield metrics rose as the amounts of N, P and K fertiliser nutrients increased. The application of 80-40-20 kg/ha N: P: K yielded the best fertiliser economy (highest benefit/ha). All parameters showed higher values in 2007–08 compared to 2006–07, which could be related to the NPK application's residual effects combined with ideal weather during the wheat crop's second growing year.

Malghani et al. [13] 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-1 was recorded with the application of 175-150-125 NPK kg ha-1. The increase in yield was 51.58 per cent higher as compared to control (2502 kg/ha), where no fertilizer was used".

A field experiment was carried out by Warraich et al. [14] to investigate the impact of nitrogen on wheat grain vigour and quality. The findings demonstrated that, in comparison to 0, 60, and 180 kg N/ha, the seeds from the 120 kg N/ha treatment exhibited greater vigour during the electrical conductivity test.

3. 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-fertlizers 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* [15].

Pawar and Suryawanshi [16] conducted an experiment to study the impact of bio-fertilizers on paddy (*Oryza sativa* L.) cultivar Jaya. The results suggest that bio-fertilizers from microorganisms can replace chemical fertilizers to increase crop production.

In order to investigate the impact of bio-fertilizers on the growth and yield of rice (*Oryza sativa* L.), Amrutha et al. [17] carried out an experiment. When comparing the results to the control, it was found that the application of POP, KAU + Azolla + AMF together produced the maximum number of grains/panicle (155.37), 1000-grain weight (24.16 g), and grain yield (3718.52 kg/ha).

Kekatpure and Chaturvedi [18] 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.

In order to investigate the impact of nitrogen levels and bio-fertilizers on the growth and yield of wheat (*Triticum aestivum* L.), Achari et al. 2021 undertook an experiment. The application of Azotobacter + Azospirillum + 140 kg/ha N increased plant height (86.07 cm), the number of tillers/plant (6.34), the dry weight (19.58 g/plant), the number of effective tillers/m2 (296.16), the length of the spike (11.25 cm), the test weight (46.93 g), the number of grains/spike (58.11), the grain yield (5.63 t/ha), and the straw yield (13.20 t/ha). However, the harvest index (33.1%) was recorded maximum with Azotobacter + 120 kg/ha N.

Aechra et al. [19] 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 differ 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.

Thejesh et al. [20] conducted “a field experiment entitled 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 2kg/ha + *Azospirillum* at 2 kg/ha has recorded highest number of grains/panicle (151.93) and number of panicles/hill (21.8).

Deva et al. [21] conducted an experiment to study the effect of liquid bio-fertilizers 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. [22] carried out an investigation to examine the impact of bio-fertilizers on wheat yield and yield components in Iraqi circumstances. Researchers came to the conclusion from this experiment that applying bio-fertilizer, regardless of type, had a good influence on the balance of nutrients in the soil at the end of the growing season, as seen by the rise in NH4, NO3, P, and K levels.

Nagwa et al. [23] conducted “an experiment to study the influence of some bio-fertilizers on wheat plants grown under graded levels of nitrogen fertilization. According to the obtained results of this experiment, application of bacterial strains *Azospirillum* + *Azotobacter* in present of 50 per cent (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.

The biostimulant effects of rhizobacteria on wheat growth and nutrient uptake depend on nitrogen application and plant development, according to an experiment carried out by Nguyen et al. in [24]. The findings showed that at

50 N, plant biomass grew most strongly in the roots during the stem-elongation stage (up to +45% with Azospirillum brasilense 65 B) and in the ears during the flowering phases (up to +19–23% depending on the strains). Thus, the biostimulant effects of PGPR (Plant growth promoting rhizobacteria) could be amplified by combining them with the right cultivation system, N rate, and plant stage.

Singh et al. [25] 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_2O_5 +40 kg K_2O with *Azotobacter* + PSB at 5 kg/ha.

A field experiment was carried out by Karmakar et al. [26] to investigate the impact of biofertilizers and green manuring on rice output. The study findings indicate that the application of 50 percent of the recommended fertiliser dose through chemical fertilisers and 25 percent of the recommended dose through FYM, in addition to in situ green manuring and blue green algae, improved growth and yield-attributing characteristics. This led to a 19.3% increase in the yield of the rice variety Lalat, compared to the recommended fertiliser dose. Additionally, improvements were noted in the soil's physico-chemical properties, including 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). The maximum net returns (22160 kg/ha) and B: C of 2.23 was also noted under the combined nutrient application.

4. EFFECT OF BIO-STIMULANTS

Biostimulant Hairamine 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 [27].

In order to investigate the genetic variability among genotypes of winter cereals for responsiveness to protein hydrolysate (PH) for grain production and its qualities, Kumar et al. 2023 carried out a field experiment. According to the study's findings, applying protein hydrolysate topically had a substantial impact on crop output, spike length, and plant height. Plants directly acquire this kind of protein hydrolysate, which has free amino acids and short peptides and promotes plant development and health. The application can lessen environmental contamination and serve as a substitute for fertilisers with a chemical base.

Kumar et al*.* [28] 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 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.

Popko et al. [29] carried out an experiment the impact of novel plant growth bio-stimulants based on amino acids on winter wheat production and grain quality. When compared to the control group without biostimulant, field experiments demonstrated that the application of products based on amino acids influenced the increase in grain yield of winter wheat (5.4 and 11%, respectively, for the application of Amino Prim at a dose of 1.0 l ha^{-1} and Aminohort at dose 1.25 l ha^{-1}).

Majathoub [30] 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 per cent), a greater number of fertile florets per spike. Nevertheless, the economic yield (grain yield) had improved by 8.2 per cent.

5. 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 nutrient supply at 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.

The integrated application of phosphorus fertiliser and farm yard manure enhances wheat

productivity by enhancing soil quality and phosphorus availability in calcareous soil under subhumid conditions, according to a field experiment carried out by Jamal et al. in [31]. The results of this experiment indicate that FYM mixture combined with fertilizer-P improved residual soil and SOM while also increasing wheat yields with a respectable P efficiency.

Dhaliwal et al. [32] 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".

In order to investigate the effects of vermi-compost N, P, S, Zn, and B fertiliser levels on the growth, yield component, and yield of maize (*Zea mays* L.), Tufa [33] carried out an experiment in Guto Gida, Western Ethiopia. With a net benefit of 140486.00 ETB/ha and a marginal rate of return of 797.98 percent, the integrated applications of vermi-compost at 5 t/ha and NPSZnB fertiliser at 100 kg/ha boosted maize production by approximately 10.36%, according to the results of this experiment. It is determined that the research area is suitable for the application of vermi-compost at a rate of 5 t/ha along with synthetic NPSZnB fertiliser at a rate of 100 kg/ha.

Saini et al. [34] 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 metre 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 per cent RDN, respectively".

In a study published, Messaoudi et al. [35] investigated the effects of potassium fertilisation on the morphological and agrophysiological characteristics of Durum wheat grown in a Mediterranean rain-fed environment. This study found that the best potassium rate to maximise durum wheat production and quality in Algerian sub-humid conditions is 100 kg K2O/ha. This recommendation was based on grain yield and evaluated agronomic features.

Kantwa et al. [36] 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 + $ZnSO_4$.

An experiment was carried out by Patyal et al. in [37] to investigate the impact of integrated nutrient management (INM) on wheat (*Triticum aestivum* L.) growth characteristics and yield. In terms of plant height (92.25 cm), dry matter accumulation (274.65 g m^{-2}) and number of tillers m-2 (92.43 m^{-2}) at harvest stage in respective years, the results indicated that among the different treatments, 100% RDF + 25% N through vermi-compost + ZnSO4 at 25 kg ha^{-1} proved to found better.

Kumar and Niwas [38] 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, days 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 per cent NPK + 5 t ha^{-1} FYM + 5 t ha^{-1} vermi-compost + PSB.

In order to investigate the effects of fertility levels and liquid biofertilizers on wheat growth and yield, Kumawat et al. [39] carried out a field experiment. The combined application of 100% RDF and Azotobacter + PSB resulted in a

considerable increase in plant height, total tillers per metre row length, effective tillers per metre row length, test weight, grain, straw and biological yield, according to the findings.

Emamu et al. [40] carried out a field study in the Toke Kutaye district of Western Ethiopia titled The effect of combined application of vermi-compost and NPS fertiliser on soil physicochemical parameters and yield of maize (*Zea mays* L.) crop. This investigation suggests that applying vermi-compost in addition to NPS fertilisers enhanced the soil's organic matter and nutrient contents, which raised crop yields. Therefore, farmers in the research area and other similar agro ecologies are encouraged to employ NPS inorganic fertiliser at 50 kg/ha and vermi-compost at 5 t/ha in an integrated manner to maintain soil fertility and sustain maize crop output.

Fazily et al. [41] 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 per cent recommended dose of N (RDN) + 25 per cent nitrogen through vermi-compost during both the consecutive years, but it did not differ significantly with application of 100 per cent RDN. On the basis of two years pooled data, T3 produced 94.96 per cent 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 gave 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. [42] carried out "a two-year field experiment on clay loam soil to evaluate the impact of integrated nutrient management (INM) practices on wheat (*Triticum aestivum* L.) growth and yield." According to the findings, compared to the other treatments, the application of 75% RDF + Vermi-compost at 1t ha^{-1} + PSB and 100% RDF + Vermi-compost at 1t ha^{-1} + PSB yielded greater yield characteristics and grain yield. Higher yield resulted in increased wheat uptake of NPK. Additionally, the soil's accessible NPK level rose in the above INM treatment compared to the control. The application of 75% RDF + vermi-compost at 1t ha^{-1} + PSB produced the greatest benefit: cost ratio (2.73).

Pandey et al. [43] 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 ZnSO4/ha although produced maximum grain yield (3.8-3.9 t ha^{-1}). However, higher benefit: cost ratio (1.5-1.7) was obtained with 10 t FYM/ha together with RDF only. Addition of 10t 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.

A field experiment named "Organic and inorganic fertilisers increase wheat yield components and biomass under rainfed condition" was carried out by Rehman et al. [44]. The findings indicate that, under rainfed conditions, the highest amounts of wheat yield components and biomass were produced with 80-60-60 kg NPK/ha and 30 t FYM/ha [45].

6. CONCLUSION

As a whole, the results of the research that have been evaluated offer compelling evidence in favour of integrated nutrient management as a comprehensive strategy for enhancing the sustainability and productivity of cropping systems based on wheat. Farmers can improve soil fertility, increase crop productivity, and reduce environmental impacts by making optimal use of both organic (vermi-compost, FYM, bio-stimulants, compost, etc.) and inorganic (macro- and micronutrients containing synthetic chemical fertilisers) inputs. This will help to ensure the long-term viability of agricultural systems.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. India stat. Selected state-wise area, production and productivity of wheat in India during 2021-22; 2023. Available:https://www.indiastat.com/table/agriculture/ selected-state-wise-area-production- productivity-w/14236.
2. Sharma S, Kandel N, Chaudhary P, Rai P. A review on integrated nutrient management on wheat (*Triticum Aestivum*

L.). Reviews in Food and Agriculture (RFNA). 2020;1(1):32-7.
3. Cui H, Luo Y, Li C, Chang Y, Jin M, Li Y, Wang Z. Effects of nitrogen forms on nitrogen utilization, yield, and quality of two wheat varieties with different gluten characteristics. European Journal of Agronomy. 2023;149:126919.
4. Yang Y, Qin Q, Li Q, Nangia V, Lan B, Mo F, Liao Y, Liu Y. Effect of nitrogen management on wheat yield, water and nitrogen utilization, and economic benefits under ridge-furrow cropping system with supplementary irrigation. Agronomy. 2023; 13(7):1708.
5. Akram SW, Singh R, Tripathi P, Roopa Achari KS, Shikha S, Shahazad AK. Effect of bio-fertilizers and nitrogen levels on growth and yield of wheat (*Triticum aestivum* L.). The Pharma Innov. J. 2021; 10(10):1979-82.
6. Qazizadah NA, Prakash R, Kumar A, Mor VS. Effect of nitrogen levels on the performance of wheat varieties under saline water irrigation in Semiarid Regions. Journal of Soil Salinity and Water Quality. 2022;14(1):15-21.
7. Kumar P, Fagodiya RK, Chaudhari SK, Singh R, Mishra AK, Singh K, Sharma DK. Effect of different nitrogen management options on nutrient uptake, biomass carbon sequestration and grain yield of maize-wheat system in reclaimed sodic soil. Journal of Plant Nutrition. 2022;45(8): 1240-52.
8. Dhaker SK, Sharma KM, Meena BS, Sharma MK, Meena LK. Effect of nutrient management on growth and productivity of wheat (*Triticum aestivum* L.) grown under rice-wheat based cropping system in south-eastern Rajasthan. The Pharma Innovation Journal. 2022;11(12):2990-4.
9. Assefa S, Haile W, Tena W. Effects of phosphorus and sulfur on yield and nutrient uptake of wheat (*Triticum aestivum* L.) on Vertisols, North Central, Ethiopia. Heliyon. 2021;7(3).
10. Klikocka H, Marks M, Barczak B, Szostak B, Podleśna A, Podleśny J. Response of spring wheat to NPK and S fertilization. The content and uptake of macronutrients and the value of ionic ratios. Open Chemistry. 2018;16(1):1059-65.
11. Leghari AH, Laghari GM, Ansari MA, Mirjat MA, Laghari UA, Leghari SJ, Laghari AH, Abbasi ZA. Effect of NPK and boron on growth and yield of wheat variety TJ-83 at Tandojam soil. Advances in Environmental Biology. 2016;10(10):209-16.
12. Khan M. Effect of different rates on NPK on the yield contributing traits and economics wheat in Rod Kohi area of Dera Ismail Khan division. Sarhad Journal of Agriculture. 2012l28(2):159-64.
13. Malghani AL, Malik AU, Sattar A, Hussain F, Abbas G, Hussain J. Response of growth and yield of wheat to NPK fertilizer. Sci. Int. 2010;24(2):185-9.
14. Warraich EA, Basra SM, Ahmad N, Ahmed R, Aftab MU. Effect of nitrogen on grain quality and vigour in wheat (*Triticum aestivum* L.). Int. J. Agric. Biol. 2002;4(4):517-20.
15. Bajracharya Sanu K, Suresh K Rai. Study on the effects of vermin-compost on the nodulation and the yield of chickpea. 2009;132-138.
16. Pawar NB, Suryawanshi NS. Impact of biofertilizers on paddy (*Oryza sativa* L.) cultivar Jaya. International Journal of Advanced Research in Science, Communication and Technology. 2022;2(3):122-128.
17. Amrutha, EA, Manju RV, Viji MM, Stephen R, John J, Alex S, Meera, AV. The influence of bio-fertilizers on growth and yield of rice (*Oryza sativa* L.). Biological Forum. 2022;14(49):23-28.
18. Kekatpure A, Chaturvedi DP. Growth and yield response of wheat in relation to the use of varieties and bio-fertilizer. Indian Journal of Pure and Applied Biosciences. 2021;9(6):53-57.
19. Aechra S, Meena RH, Jat G, Sharma J, Doodhwal K, Jat H. Effect of bio-fertilizers and split application of vermi-compost on productivity and profitability of wheat (*Triticum aestivum* L.) crop in clay loam soils. International Journal of Current Microbiology and Applied Sciences. 2020;9(4):1129-39.
20. Thejesh C, Maheshwara C, Dawson J. Studies on growth, yield and economics of rice (*Oryza sativa*. L) var. pusa basmati-1 as influenced by biofertilizers. Int. J. Curr. Microbiol. App. Sci. 2020;9(6):86-97.
21. Deva S, Vinayalakshmi CV. Effect of liquid bio-fertilizers on yield and economics ofrice. 2019;6(4):42-43.
22. Ali HH, Janno FA, Majed RE, Hamza MM. Effect of biofertilizers on yield and yield components of wheat (*Triticum aestivum*. L) under iraqi conditions. 2019;5(2):45-49.

23. Nagwa MME, Metwaly MS. Influence of some bio-fertilizers on wheat plants grown under graded levels of nitrogen fertilization. International Journal of Environment. 2019; 8(1):43-56.
24. Nguyen ML, Spaepen S, du Jardin P, Delaplace P. Biostimulant effects of rhizobacteria on wheat growth and nutrient uptake depend on nitrogen application and plant development. Archives of Agronomy and Soil Science. 2019;65(1):58-73.
25. Singh RK, Pankaj K, Birendra P, Singh SB. Effect of biofertilizers on growth, yield and economics of rice (*Oryza sativa* L.). International Research Journal of Agricultural Economics and Statistics. 2015;6(2):386-91.
26. Karmakar S, Prakash S, Kumar R, Agrawal BK, Prasad D, Kumar R. Effect of green manuring and biofertilizers on rice production. ORYZA-An International Journal on Rice. 2011;48(4):339-42.
27. De Vasconcelos AC, Chaves LH. Biostimulants and their role in improving plant growth under abiotic stresses. Biostimulants in Plant Science. 2019;3-16.
28. Kumar G, Niwas R. Effect of organic and inorganic fertilizers on growth and yield of wheat (*Triticum aestivum* L.). 2022;11(7): 1005-1009.
29. Popko M, Michalak I, Wilk R, Gramza M, Chojnacka K, Górecki H. Effect of the new plant growth biostimulants based on amino acids on yield and grain quality of winter wheat. Molecules. 2018;23(2):470.
30. Al Majathoub M. Effect of biostimulants on production of wheat (*Triticum aestivum* L.). Mediterranean Rainfed Agriculture: Strategies for Sustainability, CIHEAM, Zaragoza. 2004;147-50.
31. Jamal A, Saeed MF, Mihoub A, Hopkins BG, Ahmad I, Naeem A. Integrated use of phosphorus fertilizer and farmyard manure improves wheat productivity by improving soil quality and P availability in calcareous soil under subhumid conditions. Frontiers in Plant Science. 2023;14:1034421.
32. Dhaliwal SS, Sharma V, Shukla AK, Gupta RK, Verma V, Kaur M, Behera SK, Singh P. 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. Agriculture. 2023;13(3):556.
33. Tufa A. Vermicompost and NPSZnB fertilizer levels on maize (*Zea mays* L.) growth, yield component, and yield at guto gida, Western Ethiopia. International Journal of Agronomy. 2023;9.
34. Saini LH, Saini AK, Malve SH, Patel JP, Nand B, Chaudhary HS. Growth and yield attainment of wheat under different levels of vermicompost, biofertilizers and nitrogen. The Pharma Innovation Journal. 2023;12(6):1245-9.
35. Messaoudi A, Labdelli F, Rebouh NY, Djerbaoui M, Kucher DE, Hadjout S, Ouaret W, Zakharova OA, Latati M. Investigating the potassium fertilization effect on morphological and agrophysiological indicators of durum wheat under mediterranean rain-fed conditions. Agriculture. 2023;13(6):1142.
36. Kantwa CR, Saras PK, Vyas KG, Chaudhari HL, Choudhary RR, Patel SA, Singh SR, Patel BJ. Effect of wheat varieties and integrated nutrient management practices on nutrient content, uptake and soil nutrient status. Indian Journal of Agricultural Research. 1:5.
37. Patyal A, Shekhar C, Sachan R, Kumar D, Yadav A, Kumar G. Effect of integrated nutrient management (INM) on growth parameters and yield of wheat (*Triticum aestivum* L.). International Journal of Plant & Soil Science. 2022;34(22):962-7.
38. Kumar G, Niwas R. Effect of organic and inorganic fertilizers on growth and yield of wheat (*Triticum aestivum* L.); 2022.
39. Kumawat H, Singh DP, Jat G, Choudhary R, Singh PB, Dhayal S, Khardia N. Effect of fertility levels and liquid biofertilizers on growth and yield of wheat (*Triticum aestivum* L.). The Pharma Innovation Journal. 2021;10(9):1365-9.
40. Dhaliwal SS, Sharma V, Shukla AK, Gupta RK, Verma V, Kaur M, Behera SK, Singh Emamu T, Wakgari T. The effect of integrated application of vermicompost and NPS fertilizer on soil physicochemical properties and yield of maize (*Zea Mays* L.) crop at Toke Kutaye district, Western Ethiopia. Stechnolock Plant Biol. Res. 2021;1:1-6.
41. Fazily T, Thakral SK, Dhaka AK. Effect of integrated nutrient management on growth, yield attributes and yield of wheat. International Journal of Advances in Agricultural Science and Technology. 2021;8(1):106-18.
42. Devi KN, Singh MS, Singh NG, Athokpam HS. Effect of integrated nutrient management on growth and yield of wheat

(*Triticum aestivum* L.). Journal of Crop and Weed. 2011;7(2):23-7.

43. Pandey IB, Dwivedi DK, Pandey RK. Integrated nutrient management for sustaining wheat (*Triticum aestivum*) production under late sown condition. Indian Journal of Agronomy. 2009;54(3): 306-9.
44. Rehman S, Khalil SK, Rehman A, Saljoqi AU. Organic and inorganic fertilizers increase wheat yield components and biomass under rainfed condition. Emergence. 2008;1000(2).
45. Singh M, Kumar P, Yadav P, Sharma PK. Genetic variability among winter cereal genotypes for response to protein hydrolysate (PH) for grain yield and its attributes. Ekin Journal of Crop Breeding and Genetics. 2023;9(2): 91-7.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/116750