Asian Journal of Soil Science and Plant Nutrition

Volume 10, Issue 1, Page 457-468, 2024; Article no.AJSSPN.114515
ISSN: 2456-9682

Effect of Different Integrated Nutrient Management Approaches on Growth, Yield Attributes and Yield of Wheat (*Triticum aestivum* L.) Crop: A Review

Gurvinder Kaur [a*], Ishwar Singh [a], R.K. Behl [a] and Amit Dhankar [a]

[a] Faculty of Agriculture, Maharishi Markandeshwar (Deemed to be) University, Mullana-Ambala (Haryana)-133 207, India.

Authors' contributions

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

Article Information

DOI: 10.9734/AJSSPN/2024/v10i1252

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/114515

Review Article

Received: 12/01/2024
Accepted: 15/03/2024
Published: 27/03/2024

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, biofertilizers, 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

**Corresponding author: Email: gurvinderkaur1537628@gmail.com;*

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. This review examines response of wheat varieties to integrated nutrient management practices in wheat crop sown under normal and late planting conditions.

Keywords: Wheat; productivity; integrated nutrient management.

1. INTRODUCTION

"Wheat (*Triticum aestivum*) 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 (2022-23) is 2364.14 ha with the production of 12 mt [1].

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, biofertilizers, biostimulants and their combined applications under integrated nutrient management. Several workers have reported beneficial effects of integrated nutrient management [2]. 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 vermicompost of nutrient supply and their doses as well as time and method of application. New range of biostimulants such as hairamine (protein hydrolysate from human hair), seaweed extracts, humic acids 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.

2. 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 biofertilizers. Cui *et al*. [3] conducted "a field experiment to study the effects of nitrogen forms 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*. [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 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.* [5] 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^{-1}) and benefit cost ratio (2.08) was also obtained with this combination.

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. Singh and Singh [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).

Laghari [11] 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^{-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 per cent) were obtained with the application of NPK-120-60-60 kg/ha + B 2 per cent at tillering phase". Khan *et al*. [12] 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.

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". Warraich *et al*. [14] 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.

3. EFFECT OF VERMICOMPOST ON GROWTH AND PRODUCTIVITY OF WHEAT

Vermicompost is the product of decomposition process using various species of worms, usually red wrigglers and white worms to create a mixture of decomposing vegetable or food waste, bedding materials and vermicast. Vermicompost provides macro and micronutrients beneficial for crop growth. The application of vermicompost also exerts a positive effect on the physical and biological properties of the soil. It increases the macropore space and thus, improves the air-water relationship. It also regulates soil pH, microbial population and soil enzyme activities [15]. "Vermicompost is the best organic method to increase the soil fertility. Vermicompost and earthworms causes no harm to the soil and crop, beside this they also deliver micro and macro-nutrients which improves the crop growth [16]. Bezabeh *et al*. [17] carried out "an experiment to determine the wheat (*Triticum aestivum* L.) production and grain quality resulting from compost application and rotation with faba bean. The wheat seed nutrient concentration revealed

that effective microorganisms (EM) and vermicompost application combined with mineral fertilizer in the faba bean plot rotation resulted in the highest grain concentrations of N, P, S, Zn and Fe.

Jothi *et al*. [18] conducted an experiment to study the effect of organic manure and microbial nutrient spray on yield attributes and yield of organic rice (*Oryza sativa* L.). From the results, higher grain yield (5236 kg/ha) and straw yield (8640 kg/ha) was recorded with the application of vermicompost at 2.08 t/ha followed by the application of neem oil cake at 1.2 t/ha and composted poultry manure at 3.47 t/ha. Kizilkaya *et al*. [19] conducted an experiment to study the vermicompost effects on wheat yield and nutrient contents in soil and plant. All vermicomposted and non- vermicomposted mixtures exhibited positive effect on the yield and nutrient concentrations of wheat compared to the control pots. The vermicomposted organic waste mixtures showed comparatively better effect on plant production than the non- vermicomposted organic waste mixtures. Vermicomposted 50 per cent SS + 25 per cent HH + 25 per cent CM mixtures showed the highest positive effect on yield compared to the other treatments.

4. EFFECT OF BIOFERTILIZERS

Biofertilizers 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. Biofertilizers are carrier-based preparations containing beneficial microorganisms in a viable state intended for seed or soil application to improve soil fertility and plant growth. Biofertilizers 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. Biofertlizers 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* [20].

Pawar and Suryawanshi [21] conducted an experiment to study the impact of biofertilizers on paddy (*Oryza sativa* L.) cultivar Jaya. The results suggest that biofertilizers from microorganisms can replace chemical fertilizers to increase crop production. Amrutha *et al.* [22] conducted an experiment to study the influence of biofertilizers 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 [23] 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 biofertilizer of *Azotobacter* at 10 ml/kg seed inoculation + 500 ml/acre foliar application.

Achari *et al*. [24] conducted an experiment to study the effect of bio-fertilizers and nitrogen levels on growth and yield of wheat (*Triticum aestivum* L.). The results indicated 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^2 (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 per cent) was recorded maximum with *Azotobacter* + 120 kg/ha N.

Aechra *et al*. [25] conducted an experiment to study the effect of biofertilizers and split application of vermicompost 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 biofertilizers and vermicompost treatments and were maximum with the B5 (*Azotobacter* + PSB + KMB + ZnSB) and V_3 (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*. [26] conducted “a field experiment entitled studies on growth, yield and economics

of rice (*Oryza sativa* L.) *var.* Pusa Basmati-1 as influenced by biofertilizers. 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*. [27] conducted an experiment to study the effect of liquid biofertilizers on yield and economics of rice. The results indicated that application of biofertilizers improved yield and B: C ratio of rice.

Ali *et al*. [28] conducted an experiment to study the effect of biofertilizers on yield and yield components of wheat under Iraqi conditions. From this experiment, researchers concluded that the application of biofertilizer resulted in a positive effect on nutrients balance in the soil at the end of season regardless of type of biofertilizers as indicated by the increase in levels of NH_4, NO_3, P and K". Nagwa *et al*. [29] 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.

Nguyen *et al.* [30] 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 per cent with *Azospirillum brasilense* 65 B) at stem-elongation stage and in the ears (+19-23 per cent 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*. [31] conducted an experiment to study the effect of biofertilizers 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.

Karmakar *et al*. [32] conducted a field experiment to study the effect of green manuring and biofertilizers on rice production. The results revealed that combined application of 50 per cent of recommended dose through chemical fertilizers and 25 per cent 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 per cent) as compared to that of recommended fertilizer dose increase in nutrient uptake (21.4, 29.0 and 16.9 per cent of N, P and K, respectively) and improvement of the soil physico-chemical properties like organic carbon (0.34-0.44 per cent), 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.

5. EFFECT OF BIOSTIMULANTS

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, biostimulants applied to plants enhance nutrients' efficiency, abiotic stress tolerance and plant quality traits [33]. Kumar *et al.* [34] 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 maintained plants health. The application can be an alternative of chemical-based fertilizers and reduce the environment pollution.

Kumar *et al.* [35] 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.* [36] conducted "an experiment to study the effect of the new plant growth biostimulants 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 per cent, respectively, for the application of *AminoPrim* at a dose 1.0 l ha^{-1} and *Aminohort* at dose 1.25 l ha^{-1}) when compared to the control group without biostimulant". Majathoub [37] conducted "an experiment to study the effect of biostimulants 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.

6. 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), biofertilizers and vermicompost. Jamal *et al*. [38] conducted "a field experiment to study the integrated use of phosphorus fertilizer and farm yard 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*. [39] 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 [40] conducted an experiment to study the vermicompost 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 vermicompost 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 per cent. As a result, vermicompost application at 5 t/ha rate with synthetic NPSZnB fertilizer at 100 kg/ha is found suitable for the study area.

Saini *et al*. [41] conducted an experiment to study the growth and yield attainment of wheat under different levels of vermicompost, biofertilizers 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 vermicompost, *Azotobacter chroococcum* inoculation at 5 ml/kg seed and 100 per cent RDN, respectively". Messaoudi *et al*. [42] conducted an experiment for investigating the potassium fertilization effect on morphological and agro physiological indicates 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_2O/ha is recommended as the most effective dose to maximize durum wheat yield and quality under Algerian sub-humid conditions.

Kantwa *et al.* [43] 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 + $ZnSO_4$.

Patyal *et al*. [44] 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 per cent RDF + 25 per cent N through vermicompost + $ZnSO_4$ at 25 kg ha^{-1} proved to found better with respect to 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". Kumar and Niwas [45] 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} Vermicompost + PSB.

Kumawat *et al*. [46] conducted a field experiment to study about the effect of fertility levels and liquid biofertilizers 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*. [47] conducted a field experiment entitled 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. From this experiment, it can be concluded that the application of vermicompost 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 agro ecologies are advised to make integrated use of vermicompost at 5 t/ha and NPS inorganic fertilizer at 50 kg/ha tentatively.

Fazily *et al*. [48] 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 vermicompost 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, T_3 produced 94.96 per cent higher number of effective tillers, 34.14 per cent taller spike length, 25.47 per cent more test weight, 165.21 per cent higher grain yield and 157.13 per cent higher straw yield of wheat over control.

Thejesh *et al*. [49] conducted a field experiment entitled Studies on growth, yield and economics of rice *var.* Pusa Basmati-1 as influenced by biofertilizers. 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 (21.80)". Tanwar *et al.* [50] conducted "a field experiment to study the effect of farm yard manure and nitrogen application on growth and productivity of wheat under long term experimental conditions. The results indicated that application of 15 t/ha FYM along with 120 kg N/ha significantly improved the growth and yield of wheat.

Khatik *et al*. [51] conducted an experiment to study the effect of vermicompost and zinc application on growth and yield attribute of maize crop. From this study, it has been observed that the increased growth parameters such as chlorophyll content, plant height (30, 60 and at harvest), LAI (30, 45 and 60 DAS) with the application of vermicompost (4.5 t/ha) + zinc (5.0 kg/ha). The application of vermicompost (4.5 t/ha) + zinc (5.0 kg/ha) increased number of grain/cob (457.09), weight of grain per cob (95.04 g), seed index (33.65 g), seed yield (3896.33 kg/ha), stover yield (5415.13 kg/ha) and biological yield (9311.46 kg/ha) as compared to control. Rao *et al*. [52] conducted an experiment to study the impact of organic and inorganic source of nutrients on growth and yield of Basmati rice under SRI. From this study, it has been observed that the maximum values of growth, yield attributes and grain (56.50 and 59.00 q/ha) and straw yield (75.93 and 78.43 q/ha) were recorded with 125 per cent RDF + 25 per cent vermicompost closely followed by 125 per cent RDF + 25 per cent FYM, indicating the superiority of vermicompost over FYM. The uptake of N, P and K was highest with 125 per cent RDF + 25 per cent vermicompost and lowest in control. Net returns (₹ 79976/ha) and B: C ratio (2.22) was also highest with 125 per cent RDF + 25 per cent vermicompost.

Singh *et al.* [53] conducted an experiment to study the effect of integrated nutrient management on nutrient uptake and grain yield of wheat (*Triticum aestivum* L.) under irrigated conditions. The maximum improvement in yield

attributes and yield of crop were recorded with the application of 100 per cent RDF + vermicompost (2 t ha^{-1}). Similarly, maximum highest nutrient uptake was recorded with the application of treatments having 100 per cent RDF + vermicompost (2 t ha^{-1}) + PSB. Mohan *et al.* [54] conducted a field experiment to study the effect of integrated nutrient management on yield attributes and yield of wheat. The results revealed that the application of 100 per cent RDF *i.e.* 150:60:60 N: P: K kg/ha + 25 per cent N through vermicompost, the extent substitution of nitrogen through integrated nutrient management was obtained increased the growth, development and yield of wheat than other treatments.

Kumar *et al*. [55] conducted a field experiment to study the effect of nutrient management and moisture regime on growth and yield of wheat (*Triticum aestivum* L.). On the basis of results obtained, application of 75 per cent RDF (90:45:30 kg NPK/ha + 25 per cent N through FYM and nutrient supply system was found to be more suitable for higher yield of wheat variety Malviya 234". Malo *et al*. [56] conducted "an experiment to study the effect of inorganic and biofertilizers on growth and yield of rice in New Alluvial zone of West Bengal. The results revealed that the highest plant height, LAI, dry matter accumulation and crop growth rate were observed in 100 per cent RDF which was statistically at par with 75 per cent recommended dose of NP + 100 per cent RDK + *Azotobacter chroococcum* at 5 kg/ha".

Akhtar *et al*. [57] conducted an experiment to study the effect of different nutrient management treatments on growth, yield attributes, yield and quality of wheat (*Triticum aestivum* L.). The experimental results revealed that significantly higher values of growth parameters *viz*., plant height, dry matter per plant, number of total tillers and effective tillers and yield attributes viz., length of spike, number of grains per spike, grain weight per spike and 1000-seed weight, higher grain yield (4227 kg ha^{-1}) and straw yield (5792 kg ha^{-1}), quality parameters viz., protein content and yield were significantly higher under the treatment of RDF (120-60-60 kg N-P_2O_5-K_2O ha^{-1}) + $ZnSO_4$ at 25 kg ha^{-1} (P from DAP), being at par with treatments RDF, RDF + $ZnSO_4$ at 25 kg ha^{-1} (P from SSP), RDF (N from neem coated urea + P from SSP) and RDF (50 per cent N from neem coated urea + 50 per cent N from Zn coated urea) + P from SSP.

Desai *et al.* [58] conducted an experiment on integrated nutrient management in wheat (*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.* [59] 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 100per cent RDF + vermicompost at 1 t ha^{-1} + PSB and 75 per cent RDF + Vermicompost at 1 t ha^{-1} + 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 per cent RDF + vermicompost at 1 t ha^{-1} + PSB".

Pandey *et al*. [60] 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 $ZnSO_4$/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 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.* [61] 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".

7. 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 (vermicompost, FYM, biostimulants, 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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Indiastat. Selected state-wise area, production and productivity of wheat in India during 2021-22. https://www.indiastat.com/table/agriculture/selected-state-wise-area-production-productivity-w/14236. 2023.
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 Sep 1;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 Jun 26;13(7):1708.
5. 5.Akram SW, Singh R, Tripathi P, Roopa G. Effect of Phosphorus and Sulphur on yield and economics of Wheat (*Triticum aestivum* L.). The Pharma Innovation Journal. 2022;11(5):599-602.
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 May 9;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 Mar 1;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 Oct 22;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 Oct 1;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. 2012 Jun 30;28(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. Rana SS, SCIENTIST S. Biological intensive nutrient management: Vermicompost. BINM: Vermicompost. 2018.
16. Asewar, B. V., S. S. Bainade, O. D. Kohire, and P. S. Bainade. Integrated use of vermicompost and inorganic fertilizer in chickpea. 2003; 205-206.
17. Bezabeh MW, Haile M, Sogn TA, Eich-Greatorex S. Wheat (*Triticum aestivum*) production and grain quality resulting from compost application and rotation with faba bean. Journal of Agriculture and Food Research. 2022 Dec 1;10:100425.
18. Jothi M, Manivannan V, Mohamed Yassin M, Ganesan K. Effect of organic manure and microbial nutrient spray on yield attributes and yield of organic rice (*Oryza sativa* L.). 2021;209-15.

19. Kizilkaya R, Hepsen Turkay FS, Turkmen C, Durmus M. Vermicompost effects on wheat yield and nutrient contents in soil and plant. Archives of Agronomy and Soil Science. 2012 Oct 1;58(sup1):S175-9.
20. Bajracharya, Sanu K., and Suresh K. Rai. Study on the effects of vermicompost on the nodulation and the yield of chickpea. 2009; 132-138.
21. 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.
22. Amrutha, EA, Manju RV, Viji MM, Stephen R, John J, Alex S, Meera, AV. The influence of biofertilizers on growth and yield of rice (*Oryza sativa* L.). Biological Forum. 2022; 14 (49): 23-28.
23. 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.
24. 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.
25. Aechra S, Meena RH, Jat G, Sharma J, Doodhwal K, Jat H. Effect of biofertilizers and split application of vermicompost 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.
26. 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.
27. Deva S, Vinayalakshmi CV. Effect of liquid biofertilizers on yield and economics of rice. 2019; 6 (4): 42-43.
28. 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.
29. 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.
30. 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 Jan 2;65(1):58-73.
31. 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.
32. 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.
33. De Vasconcelos AC, Chaves LH. Biostimulants and their role in improving plant growth under abiotic stresses. Biostimulants in plant science. 2019 Nov 7:3-16.
34. 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 Jan 8;9(2):91-7.
35. Kumar G, Niwas R. Effect of organic and inorganic fertilizers on growth and yield of wheat (*Triticum aestivum* L.). 2022; 11 (7): 1005-1009.
36. 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 Feb 21;23(2):470.
37. Al Majathoub M. Effect of biostimulants on production of wheat (*Triticum aestivum* L.). Mediterranean Rainfed Agriculture: Strategies for Sustainability, CIHEAM, Zaragoza. 2004:147-50.
38. 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 Jan 23;14:1034421.
39. 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 Feb 24;13(3):556.

40. 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 Mar 9;2023.
41. 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.
42. 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 May 29;13(6):1142.
43. 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.
44. 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 Aug 24;34(22):962-7.
45. Kumar G, Niwas R. Effect of organic and inorganic fertilizers on growth and yield of wheat (*Triticum aestivum* L.). 2022.
46. 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.
47. Emamu T, Wakgari T. The effect of integrated application of Vermicompost and NPS fertilizer on soil physicochemical properties and yield of maize (*Zea May* L.) crop at Toke Kutaye district, Western Ethiopia. Stechnolock Plant Biol. Res. 2021;1:1-6.
48. 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.
49. 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.
50. Kavinder VS, Hooda YP, Malik D, Kavita H. Effect of farm yard manure and nitrogen application on growth and productivity of wheat under long term experimental conditions. Curr. J. Appl. Sci. Technol. 2019;35:1-7.
51. Khatik R, Singh DP, Jain HK, Yadav KK, Choudhary, RS, Bunker, RN. Effect of vermicompost and zinc application on growth and yield attribute of maize crop. International Journal of Current Microbiology and Applied Sciences. 2019;8 (8):3077-3082.
52. Rao A, Singh NB, Pandey D. Impact of organic and inorganic source of nutrients on growth and yield of basmati rice under SRI. International Journal of Current Microbiology and Applied Science. 2019;8(12):1728-34.
53. Singh G, Kumar S, Singh G, Singh N. Effect of integrated nutrient management on nutrient uptake and grain yield of wheat (*Triticum aestivum* L.) under irrigated conditions. Journal of Pharmacognosy and Phytochemistry. 2019;8(1):1077-80.
54. Mohan B, Kumar P, Yadav RA. Effect of integrated nutrient management on yield attributes and yield of wheat (*Triticum aestivum* L.). Journal of Pharmacognosy and Phytochemistry. 2018;7(1):1545-7.
55. Kumar A, Singh AK, Kumar S, Kumar D, Gopal T, Pandey D, Pandey VK. Effect of nutrient management and moisture regime on growth and yield of wheat (*Triticum aestivum* L.). Journal of Pharmacognosy and Phytochemistry. 2018;7(1):610-3.
56. Malo M, Ghosh A, Dutta D, Murmu K. Effect of inorganic and bio-fertilizers on growth and yield of rice in New Alluvial Zone of West Bengal. Journal of Pharmacognosy and Phytochemistry. 2018;7(1):576-80.
57. Akhtar N, Ramani VB, Yunus M, Femi V. Effect of different nutrient management treatments on growth, yield attributes, yield and quality of wheat (*Triticum aestivum* L.). International Journal of Current Microbiology and Applied Sciences. 2018;7: 3473-3479.
58. Desai HA, Dodia IN, Desai CK, Patel, MD, Patel, HK. Integrated nutrient management

in wheat (*Triticum aestivum* L.). Trends in Biosciences. 2015; 8(2):472-475.

59. 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.
60. 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.
61. 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).

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/114515