Effect of different integrated nutrient management approaches on growth, yield attributes and yield of wheat (*Triticumaestivum*L.)crop:A review

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, biostimulants 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 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

INTRODUCTION

"Wheat (*Triticumaestivum*) is the world's principal and commercially important food crop. It belongs to thegrass family *Poaceae*. Global wheat consumption has increased in the past four decades to around 781million 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" (Anonymous, 2023).

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 (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 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.

- **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*. (2023) 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*. (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 @ 80 kg/ha + Sulphur @ 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 (Rs. 99,187/ha), net returns (Rs. 67,049 ha^{-1}) 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 upto 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(2022) conducted "a field experiment to study nitrogen management in late sown wheat. The results indicated that application of 50per cent RDN at sowing + 3per cent urea foliar application at tillering and earing recorded 41.8, 52.6 and 30.6per cent higher grain yield than other treatments".Dhaker*et al*. (2022) conducted "a 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 150per 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 150per cent RDF (Rs. 106464/ha), however, 125per cent RDF (Rs. 103460/ha) and RDF + FYM (Rs. 9907/ha) as well as RDF + Zn + S (Rs.99155/ha) were found at par with 150per cent RDF".

Assefa*et al*. (2021) conducted "a 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 (54.9per cent)".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(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^{-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 (42.5per cent) were obtained with the application of NPK-120-60-60 kg/ha + B 2per cent 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".

Malghani*et 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^{-1} was recorded with the application of 175-150-125 NPK Kg ha^{-1}. The increase in yield was 51.58per 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 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" (Rana, 2018)."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" (Asewar*et al*., 2004).Bezabeh*et al*. (2022) carried out "an experiment to determine the wheat (*Triticumaestivum* L.) production and grain quality resulting from compost application and rotation with faba bean. The wheat seed nutrient concentration revealed that effective microorganisms (EM) andvermicompost 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*. (2021) 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 @ 2.08 t/ha (OM_3) followed by the application of neem oil cake @ 1.2 t/ha (OM_5) and composted poultry manure@ 3.47 t/ha (OM_4)".Kizilkaya*et al*. (2012)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 50per cent SS + 25per cent HH + 25per cent CM mixtures showed the highest positive effect on yield compared to the other treatments".

- **Effect of biofertilizers**

Biofertilizers are considered as an important constituent of sustainable agriculture. The cropproductivity 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 (Bajracharya and Rai, 2009). "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. Thecrop productivity and profitability can be improved by the inoculation of pulse crops with phosphorus solubilizing bacteria (PSB) and *Rhizobium"* (Bajracharya and Rai, 2009).

Pawar and Suryawanshi (2022) 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".Amruth*a et al.* (2022) 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 (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 biofertilizer of *Azotobacter* @ 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 (*Triticumaestivum*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 (33.1per cent) was recorded maximum with *Azotobacter* + 120 kg/ha N".

Aechra*et al*. (2020) conducted "an experiment to study the effect of biofertilizers and split application of vermicompost on productivity and profitability of wheat (*Triticumaestivum*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 (50per cent at sowing + 50per cent at tillering) as compared to control. The highest net return and B: C ratio was also obtained with this combination".

Thejesh*et al*. (2020) 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 @ 2kg/ha + *Azospirillum* @ 2 kg/ha has recorded highest number of grains/panicle (151.93) and number of panicles/hill (21.8)".Deva*et al*. (2019) 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*. (2019) 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*. (2019) 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 50per cent (nitrogen of recommended dose) could save 50per 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*. (2018) 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 (upto + 45per cent with *Azospirillumbrasilense* 65 B) at stem-elongation stage and in the ears (+19-23per 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*. (2015) 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 @ 5 kg/ha".

Karmakar*et al*. (2011) 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) andB: C of 2.23 was also noted under the combined nutrient application".

- **Effect of biostimulants**

"Biostimulanthairamine 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" (De Vasconcelos*et al.,* 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 maintained plants health. The application can be an alternative of chemical-based fertilizers and reduce the environment pollution".

Kumar *et al.* (2021) 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*etal.* (2018) 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 lha^{-1} and *Aminohort* at dose 1.25 lha^{-1}) when compared to the control group without biostimulant".Majathoub (2004) conducted "an experiment to study the effect of biostimulants on production of wheat (*Triticumaestivum*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".

- **Effect of integrated nutrient management onplant 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*. (2023) 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*. (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 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 10.36per cent, with a net benefit of 140486.00 ETB/ha and a marginal rate of return of 797.98per 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*. (2023) 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, *Azotobacterchroococcum* inoculation @ 5 ml/kg seed and 100per cent RDN, respectively".Messaoudi*et al*. (2023) conducted "an experiment for investigating the potassium fertilization effect on morphological and agrophysiological 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.* (2023) 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

100per 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 100per cent RDF + *Azotobacter* + PSB. However, significantly higher organic carbon and zinc content in soil was observed under 50per cent RDF + 25per cent N through FYM + *Azotobacter* + PSB + $ZnSO_4$".

Patyal*et al*. (2022) conducted "an experiment to study the effect of integrated nutrient management (INM) on growth parameters and yield of wheat (*Triticumaestivum*L.). The results showed that among various treatments, 100per cent RDF + 25per cent N through vermicompost + $ZnSO_4$ @ 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 (2022) conducted "an experiment to study the effect of organic and inorganic fertilizers on growth and yield of wheat (*Triticumaestivum*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 100per cent NPK + 5 t ha^{-1} FYM + 5 t ha^{-1}Vermicompost + PSB".

Kumawat*et al*. (2021) 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 tillersper metre row length, effective tillersper metre row length, test weight, grain; straw and biological yield was observed with the combine application of 100per cent RDF and *Azotobacter* + PSB".Emamu*et al*. (2021) 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 @ 5 t/ha and NPS inorganic fertilizer @ 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 100per 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 100per cent RDN. On the basis of two years pooled data, T_3 produced 94.96per cent higher number of effective tillers, 34.14per cent taller spike length, 25.47per cent more test weight, 165.21per cent higher grain yield and 157.13per cent higher straw yield of wheat over control".
Thejesh*et al*. (2020) 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 @ 2 kg/ha + *Azospirillum* @ 2 kg/ha has recorded highest number of grains/panicle (151.93) and number of panicles/hill (21.80)".Tanwar*et al.* (2019) 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*. (2019) 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*. (2019) 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 125per cent RDF + 25per cent vermicompost closely followed by 125per cent RDF + 25per cent FYM, indicating the superiority of vermicompost over FYM. The uptake of N, P and K was highest with 125per cent RDF + 25per cent vermicompost and lowest in control. Net returns (Rs. 79976/ha) and B: C ratio (2.22)was also highest with 125per cent RDF + 25per centvermicompost".

Singh *et al.* (2019) conducted "an experiment to study the effect of integrated nutrient management on nutrient uptake and grain yield of wheat (*Triticumaestivum* L.) under irrigated conditions. The maximum improvement in yield attributes and yield of crop were recorded with the application of 100per cent RDF + Vermicompost (2 t ha^{-1}). Similarly, maximum highest nutrient uptake was recorded with the application of treatments having 100per cent RDF + vermicompost (2 t ha^{-1}) + PSB.Mohan *et al.* (2018) 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 100per cent RDF *i.e.* 150:60:60 N: P: K kg/ha + 25per 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*. (2018) conducted "a field experiment to study the effect of nutrient management and moisture regime on growth and yield of wheat (*Triticumaestivum* L.). On the basis of results obtained, application of 75per cent RDF (90:45:30 kg NPK/ha + 25per 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*. (2018) 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 100per

cent RDF which was statistically at par with 75per cent recommended dose of NP + 100per cent RDK + *Azotobacterchroococcum* @ 5 kg/ha".

Akhtar *et al*. (2018) conducted "an experiment to study the effect of different nutrient management treatments on growth, yield attributes, yield and quality of wheat (*Triticumaestivum*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}) + $ZnSO_4$ @ 25 kg ha^{-1} (P from DAP), being at par with treatments RDF, RDF + $ZnSO_4$ @ 25 kg ha^{-1} (P from SSP), RDF (N from neem coated urea + P from SSP) and RDF (50per cent N from neem coated urea + 50per cent N from Zn coated urea) + P from SSP".

Desai *et al.* (2015) conducted "an experiment on integrated nutrient management in wheat (*Triticumaestivum* 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.* (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 (*Triticumaestivum* L.). The results revealed that the application of 100per cent RDF + vermicompost @ 1 t ha^{-1} + PSB and 75per cent RDF + Vermicompost @ 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 75per cent RDF + vermicompost @ 1 t ha^{-1} + PSB".

Pandey *et al*. (2009) conducted "a field experiment to find out the effect of integrated nutrient management on productivity of late sown wheat (*Triticumaestivum* L.). The results showed that application of 150per 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.* (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 (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.

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