International Journal of Plant & Soil Science

Volume 35, Issue 22, Page 823-832, 2023; Article no.IJPSS.109745
ISSN: 2320-7035

Combination of Fertilizer and Growth Regulators Impact on Nutrient Balance in Wheat Crop (*Triticum aestivum* L.)

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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/IJPSS/2023/v35i224193

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/109745

Original Research Article

Received: 02/10/2023
Accepted: 07/12/2023
Published: 08/12/2023

ABSTRACT

A field experiment was conducted during the *rabi* season of 2020 at All India Coordinated Research Project (AICRP) on Wheat, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.) to evaluate nutrient balance under the optimization of fertilizer levels with plant growth regulators. The experiment was laid out in a randomized block design comprising nine treatment of different dose of fertilizer along with plant growth regulators namely chlormequat chloride and tebuconazole applied at the rates of 0.2% and 0.1%, respectively and replicated three times. The recommended dose of fertilizer, 120:60:40 kg NPK ha^{-1} was applied as per treatment. The result showed that using 150% recommended doses of NPK, recorded higher value of available nitrogen (297.320 kg ha^{-1}),

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phosphorus (18.970 kg ha^{-1}) and potassium (311.630 kg ha^{-1}) content in soil after the harvest of wheat was significantly influenced by the application of different doses of fertilizer, while lowest available content of all the three major nutrients was recorded from control. Growth regulators had no significant influence on the available nitrogen, phosphorus and potassium content in soil. The highest nitrogen content in both grain and straw were observed with the application of 150% recommended doses of NPK with growth regulators (1.99%) and (0.567%), respectively. Phosphorus content and potassium content both in grain and straw were significantly influenced by fertilizer doses, highest value recorded with 150% recommended doses of NPK and the lowest phosphorus and potassium content in both grain and straw were recorded in control while all the other treatments receiving fertilizers with or without being at par with each other. Uptake of all the major nutrients viz., nitrogen, phosphorus and potassium showed the similar trend with significantly highest uptake recorded with the application of 150% recommended doses of NPK with growth regulator and optimal NPK application demonstrated a positive nutrient balance in the soil. It concluded that nutrient management with growth regulator in wheat, economically viable and ecologically sound option to extend these benefits of balanced nutrition in enhancing both crop production and soil heath.

Keywords: Fertilizer; nutrient balance sheet; plant growth regulator; uptake of nutrient; wheat.

1. INTRODUCTION

Wheat (*Triticum aestivum* L.) ranks as one of the world's foremost cereal crops, which can be grown in broad range of altitudes and latitudes. Renowned for its abundant reserves of carbohydrates, distinctive protein profile, fat and minerals (zinc, iron) and also contains good source of vitamins such as thiamine and vitamin-B, wheat serves as a staple in both human and animal diets [1,2]. It accounts for around 20% of total dietary calories consumed by human [3]. Wheat is grown 217.02 million hectares, yielding an impressive 765.4 million metric tons worldwide. In India, it is grown in 31.45 million hectare area with production of 107.592 million metric tons and productivity of 3.42 metric tonnes/ha [4]. In Madhya Pradesh, wheat is grown in 10.02 million hectares area with the production of 16.52 million metric tonnes and productivity of 3298 kg per hectare [5]. The global demand for wheat is projected to reach around 840 million tonnes by 2030 [6] and the estimated wheat production target for India by the year 2050 is approximately 140 million tonnes. This projection takes into account the increasing demand for consumption and trade driven by the growing population [7]. In order to produce more food, feed, and fiber from a smaller amount of land, nutrient application in agricultural systems will probably increase in the future years. However, achieving optimal wheat production while maintaining a nutrient-balanced ecosystem remains a formidable challenge. To sustainably enhance wheat crop yields and nutritional quality, it is imperative to optimize nutrient management practices while ensuring a balanced uptake of essential nutrients by the plants.

Nutrient balance in crop production is crucial for achieving optimal growth and yield. Imbalances in essential nutrients can lead to reduced crop productivity, increased susceptibility to diseases and pests, and compromised nutritional quality. Traditional approaches to nutrient management have often focused on the application of fertilizers to provide plants with the necessary elements for growth. However, these practices have sometimes led to nutrient imbalances in the soil, affecting not only crop performance but also environmental sustainability. To address these challenges, contemporary agricultural research has explored innovative approaches aimed at optimizing fertilizer use while preserving nutrient balance. One such approach involves the integration of plant growth regulators (PGRs) with judiciously optimized fertilizer levels. Recent reports suggest that plant growth regulator can enhance wheat growth and yield [8,9,10]. Plant growth regulators are synthetic or naturally occurring compounds that influence the growth and development, including nutrient uptake, root development, and photosynthesis of plants in a targeted manner. By harnessing PGRs alongside precise fertilizer management, we have the potential to revolutionize wheat cultivation, achieving a dual objective of enhanced yield and improved nutrient balance.

This research investigates the synergistic effects of these two interventions on nutrient uptake, utilization, and distribution within the wheat plants. The ultimate goal of this study is to contribute to sustainable and efficient wheat production practices that not only increase crop yields but also promote nutrient-balanced wheat, aligning with the broader objectives of global food security and nutrition.

2. MATERIALS AND METHODS

The field trial was carried out as part of the All India Coordinated Wheat Improvement Project during the *rabi* season of 2020–21 at the research farm of the Jawaharlal Nehru Krishi Vishwa Vidyalaya in Jabalpur, Madhya Pradesh to evaluate the Combination of fertilizer and plant growth regulators impact on nutrient balance in wheat crops (*Triticum aestivum* L). The experiment was laid out in randomized block design with three replications, consisting nine treatments *viz*., T_1- 50% recommended doses of NPK, T_2 - 75% recommended doses of NPK, T_3 - 100% recommended doses of NPK, T_4 - 125% recommended doses of NPK, T_5 -150% recommended doses of NPK, T_6 -100% recommended doses of NPK with growth regulators applied at first node stage and boot leaf stage (45 and 65 DAS, respectively), T_7 - 125% recommended doses of NPK with growth regulators applied at first node stage and boot leaf stage, T_8 -150% recommended doses of NPK with growth regulators applied at first node stage and boot leaf stage, T_9 -Control (No fertilizer and growth regulators spray). The annual rainfall received during the growing season was 1350 mm in 2020-21. The soil of the experimental field was classified in clay loam in texture with a pH of 7.2, it contained a moderate amount of organic carbon (0.62%), low in available nitrogen (288.00 kg ha^{-1}), medium in available phosphorus (16.66 kg ha^{-1}) and available potassium (302.00 kg ha^{-1}). The concentration of soluble salts in the soil was below the harmful limit, measuring at (0.33ds m^{-1}). The field preparation included a deep ploughing using a moldboard plough followed by two cross harrowing and planking. The Wheat variety MP 3382 was sown on November 16, 2020 and harvested on April 8, 2021, with a seeding rate of 100kg ha-1 with the spacing of 20 cm row- to- row. Recommended dose of fertilizer i.e N, P and K @ 120, 60 and 60 kg ha^{-1}, respectively was applied according to the treatment. Half dose of nitrogen was supplied through Di-ammonium phosphate (DAP) and urea, with full dose of phosphorus (P_2O_5) as DAP and potash (K_2O) as muriate of potash were applied before sowing of seeds as basal application. The remaining half dose of nitrogen was applied in two equal splits as top-dressing during crown root initiation (CRI) and jointing stage, following the specific treatment plan. The PGR used during experiment was chlormequat chloride available as Lihocin and tebuconazole available as Folicur. The crop was grown under irrigated conditions, receiving a total of six irrigations at critical growth stages. Weeds control was managed through control two-hand weeding was done in all treatment plots with the help of weeding hook as needed. Gap filling was performed ten days after sowing to maintain the required plant population. The regular biometric observation were recorded at periodic intervals of 15, 30, 60, 90 days after sowing (DAS) and at the harvest stage. The observations were recorded on yield attributes and yield using standardized procedures [11]. The collected data were subjected to statistically analysis using the analysis of variance (ANOVA) technique, following the procedure suggested by Panse and Sukhatme [12]. Treatment comparisons are made at a 5% levels of significance.

CD = S.Ed. X t (0. 05) (edf)

Were,

S. Em$\pm$} = standard error of treatment means
S. Ed$\pm$} = standard error of difference between treatment means
C.D = Critical difference

2.1 Soil Analysis

The soil samples were collected with the help of Khurpi (Spud) from each plot of the above-mentioned treatments representing the plough layer (0-15 cm) after harvest of wheat. Composite representative soil samples were obtained from these samples for each treatment. Each Composite sample consisted of a mixture of three sub samples from different site of each plot to secure representative sample of the plot selected for sampling. The mass of each collected sample was reduced to about 500 g by adopting the technique of quartering. These soil samples were air-dried, crushed by wooden pestle and mortar and were passed through 2 mm stainless steel sieve and stored in polythene bags at room temperature for analysis. Soil pH was determined in a 1:2.5 soil water suspension by glass electrode pH meter of Jackson [13]. Electrical conductivity of soil suspension used for pH determinations were allowed to settle down and conductivity of supernatant liquid was determined by using conductivity meter [13]. The results are expressed in dS/m at 25ºC. Organic Carbon content was determined by Walkley and Black's rapid titration method [13]. Available nitrogen (N) in soil was determined by adapting the alkaline permanganate method of Subbiah and Asija [14]. Available phosphorus content of soil was estimated by extraction procedure as described by Olsen et al. [15]. The absorbance of blue color was read after 10 minutes, on spectrophotometer at 660 nm wavelength. Available Potassium (K) in soil was extracted with neutral normal ammonium acetate with flame photometer [13].

2.2 Plant Analysis

The plant sample (*viz*., wheat stover, grain,) were taken after harvesting from each plot for chemical analysis. Oven dried plant samples were grinded to fine powder in Willey mill with stainless steel blades. The powdered plant samples were used for nutrient analysis. The plant samples were subjected to wet digestion for estimating various nutrients in the stover, grain. For nutrients other than N, the plant sample was digested in a di-acid mixture i.e., Mixture of HNO_3 and perchloric acid (4:1). This mixture was added for estimation of P and K. One-gram processed sample was taken in 50 ml flask and was placed in a low heat digestion chamber (160 ºC). Then, heated at higher temperature (210 ºC) until the production of red NO_2 fumes ceased. The contents were further evaporated until the volume was reduced to about 3 to 5 ml but not to dryness, indicating completion of digestion. After cooling flask, the solution was diluted with glass-distilled water and volume was made up to 100 ml volumetric flask. Aliquots of this solution were used for the determination of P and K. Nutrient content (%) of stover, grain i.e., nitrogen, phosphorus and potassium were determined on dry weight basis at harvesting as per standard procedures. Nitrogen (N) concentration in prepared samples was determined by Modified Kjeldahl method as described by Prasad et al. [16]. Phosphorus (P) well ground seed and straw samples were digested in diacid mixture of HNO_3 and $HClO_4$ (4:1) and phosphorus concentration in the extract was determined by Vanado molybdate yellow colour method as described by Koeing and Johnson [17]. Potassium (K) concentraton in the diacid was determined by Flame-photometric method as described by Black [18].

Uptake of NPK by Straw:

$$\text{Nutrient uptake (kg/ha)} = \frac{\text{of NPK concentration in straw x Straw yield (kg/ha)}}{100}$$

Uptake of NPK by grain:

$$\text{Nutrient uptake (kg/ha)} = \frac{\text{\% of NPK concentration in grain x Grain yield (kg/ha)}}{100}$$

Total uptake:

Total uptake of N, P and K was calculated for each treatment separately by using the following formula.

Total nitrogen uptake (kg ha^{-1}) = N uptake by grain + N uptake by straw

Uptake of N, P and K by wheat plants was expressed in kg ha^{-1}

2.3 Nutrient Balanced Sheet

Based on apparent gain or loss of nutrient, an attempt was made to establish fate of nutrient available in soil, added through different sources and crop removals in one season. The nutrient balance sheet was worked out as follows:

Expected nutrient balance (D) = (A+B) - C

Were,

A = Initial nutrient status of soil
B = Nutrient added as per treatment (Through fertilizer)
C = Nutrient taking by crop

Apparent gain /loss (F) = E -D

Were,

E = Actual nutrient balance i.e., the available nutrient status of soil after harvest of the crop

Actual gain / loss (G) = E – A

3. RESULTS AND DISCUSSION

3.1 Soil Analysis

3.1.1 Available nitrogen

The data revealed the significant effect of fertilizer doses on the available nitrogen content of the soil after the harvest of wheat crop showed significantly highest available nitrogen content with the 150% recommended doses of NPK treatment followed by 150% recommended doses of NPK with growth regulators. Significantly lowest value of available nitrogen was recorded with the treatment in which no fertilizers was added. The differences in available nitrogen content in soil after the harvest of wheat were due to different quantities of nitrogen added to the soil.

3.1.2 Available phosphorus

The data revealed significant differences in available phosphorus content due to fertilizer doses with significantly higher value recorded when the crop was fertilized with 150% recommended doses of NPK followed by the application of 125% recommended doses of NPK with growth regulators and 150% recommended doses of NPK with growth regulators and control in that order, each treatment differing significantly from one another. The differences in available phosphorus content in soil were due to different quantities of phosphorus added to the soil.

3.1.3 Available potassium

The available potassium content in soil recorded after the harvest of wheat crop was significantly impacted by the fertilizer application. Significantly highest value was recorded with the application of 150% of recommended dose of NPK followed by 150% recommended doses of NPK with growth regulators and significantly lowest available potassium content was recorded in control treatment. The differences were due to the differences in the quantities of potassium added, its uptake in different treatments and its subject to various losses.

Thus growth regulators had no significant influence on the available nitrogen, phosphorus and potassium content in soil after the harvest. Similar finding recorded by Jat et al. [19] he reported significantly higher values of available NPK in soil when the wheat crop was fertilized with the higher dose of fertilizer (120:60:60) as compared to other doses.

Table 1. Available nutrients in soil after harvest of wheat crop

Treatment	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
50% recommended doses of NPK	280.750	14.760	289.450
75% recommended doses of NPK	283.630	15.010	291.880
100% recommended doses of NPK	289.860	17.410	304.560
125% recommended doses of NPK	291.580	18.110	307.950
150% recommended doses of NPK	297.320	18.970	311.630
100% recommended doses of NPK with growth regulators	289.770	17.560	304.350
125% recommended doses of NPK with growth regulators	290.580	18.560	307.300
150% recommended doses of NPK with growth regulators	296.420	18.220	311.360
Control (No fertilizer and growth regulators spray)	278.050	13.220	287.470
S.E.M ±	5.3468	0.3051	4.1355
C.D. @ 5%	16.0296	0.9148	12.3983

3.2 Plant Studies

3.2.1 Nitrogen content

The data revealed that nitrogen content in both grain and straw was significantly influenced by the application of different doses of fertilizers and growth regulators. Significantly higher nitrogen content in grain with the application of 150% of recommended dose of NPK with growth regulators followed by application of 150% of recommended dose of NPK. Significantly lowest nitrogen content in grain and straw was recorded in control treatment where no fertilizers were added.

3.2.2 Phosphorus content

Data revealed the significant effect of fertilizer doses and growth regulators on phosphorus content in both grain and straw. Significantly higher phosphorus content in grain and straw was recorded with the application of 150% of recommended dose of NPK and significantly lowest phosphorus content in grain and straw was recorded in control treatment. This was due to the reason that soil in the control treatment was not able to provide the required quantities of phosphorus to the crop thus resulting in significantly lower phosphorus content.

3.2.3 Potassium content

The data revealed that potassium content in both grain and straw was significantly influenced by the application of different doses of fertilizers. Significantly highest potassium content in wheat grain and straw was recorded with the application of 150% recommended dose of NPK this treatment was followed by application of 125% recommended dose of NPK. Significantly lowest potassium content in grain and straw was recorded in control where no fertilizers were added.

Similar finding was reported by Rehman et al. [20], Kumar et al. [1], Pandey et al. [21], Mattas et al. [22], Shahi et al. [23], Paswan et al. [24] and Chesti et al. [25]. These results was contradiction with Singh et al. [26] he reported that the increment in N uptake was probably due to improvement in soil conditions, which promoted the proliferation of roots and plant demand, which in turn drew more nutrients from larger area and greater depth. Under various spray treatments, maximum NPK uptake was recorded in 150% recommended doses of NPK with growth regulators. Effect of growth retardants on growth, biochemical, yield and yield components of wheat revealed that the application of Cycocel + Folicur in wheat crop recorded higher root growth due to maximum nutrient uptake, and protein content compared to control.

3.3 Nutrient Balance Sheet

3.3.1 Apparent gain (+) or loss (-)

The result revealed that apparent gain (+) or loss (-) of NPK nutrient was recorded as control based treatment gave higher N positive value of apparent N and P with the value (63.03) and

Table 2. Uptake of nutrient (on % basis) as influence by different treatment

Treatment	N Content		P Content		K Content	
	Grain	Straw	Grain	Straw	Grain	Straw
50% recommended doses of NPK	1.84	0.543	0.410	0.064	0.467	1.64
75% recommended doses of NPK	1.88	0.556	0.422	0.069	0.467	1.69
100% recommended doses of NPK	1.95	0.562	0.429	0.074	0.471	1.75
125% recommended doses of NPK	1.97	0.564	0.432	0.076	0.482	1.79
150% recommended doses of NPK	1.98	0.566	0.437	0.077	0.487	1.81
100% recommended doses of NPK with growth regulators	1.96	0.563	0.425	0.075	0.473	1.76
125% recommended doses of NPK with growth regulators	1.97	0.565	0.429	0.076	0.478	1.78
150% recommended doses of NPK with growth regulators	1.99	0.567	0.432	0.078	0.481	1.80
Control (No fertilizer and growth regulators spray)	1.82	0.525	0.399	0.059	0.47	1.61
S.E.M ±	0.03	0.0071	0.0063	0.0013	0.0009	0.026
C.D. @ 5%	0.10	0.0213	0.0191	0.0040	0.0026	0.077

Table 3. Nutrient balance sheet for nitrogen as influence by different treatment

	Initial soil nutrient (A)	Nutrient added (B)	Nutrient uptake (C)	Expected balance in soil D = (A+B)- C	Actual soil fertility status (E)	Apparent gain (+) or loss (-) F= E-D	Net gain (+) or loss (-) G= E-A
50% recommended doses of NPK	288	60	83.65	264.35	280.75	16.40	-7.25
75% recommended doses of NPK	288	90	91.24	286.76	283.63	-3.13	-4.37
100% recommended doses of NPK	288	120	114.81	293.19	289.86	-3.33	1.86
125% recommended doses of NPK	288	150	124.60	313.40	291.58	-21.82	3.58
150% recommended doses of NPK	288	180	133.30	334.70	297.32	-37.38	9.32
100% recommended doses of NPK with growth regulators	288	120	139.40	268.60	289.77	21.17	1.77
125% recommended doses of NPK with growth regulators	288	150	143.81	294.19	290.58	-3.61	2.58
150% recommended doses of NPK with growth regulators	288	180	153.19	314.81	296.42	-18.39	8.42
Control (No fertilizer and growth regulators spray)	288	00	72.98	215.02	278.05	63.03	-9.95

Table 4. Nutrient balance sheet for phosphorus as influence by different treatment

Treatment	Initial soil nutrient (A)	Nutrient added (B)	Nutrient uptake (C)	Expected balance in soil D = (A+B) - C	Actual soil fertility status (E)	Apparent gain (+) or loss (-) F= E-D	Net gain (+) or loss (-) G= E-A
50% recommended doses of NPK	16.66	30	15.87	30.79	14.76	-16.03	-1.9
75% recommended doses of NPK	16.66	45	17.63	44.03	15.01	-29.02	-1.65
100% recommended doses of NPK	16.66	60	17.05	59.61	17.41	-42.20	0.75
125% recommended doses of NPK	16.66	75	16.22	75.44	18.11	-57.33	1.45
150% recommended doses of NPK	16.66	90	17.69	88.97	18.97	-70.00	2.31
100% recommended doses of NPK with growth regulators	16.66	60	18.24	58.42	17.56	-40.86	0.9
125% recommended doses of NPK with growth regulators	16.66	75	19.25	72.41	18.56	-53.85	1.9
150% recommended doses of NPK with growth regulators	16.66	90	20.93	85.73	18.22	-67.51	1.56
Control (No fertilizer and growth regulators spray)	16.66	00	9.47	7.19	13.22	6.03	-3.44

Table 5. Nutrient balance sheet for potassium as influence by different treatment

Treatment	Initial soil nutrient (A)	Nutrient added (B)	Nutrient uptake (C)	Expected balance in soil D = (A+B) – C	Actual soil fertility status (E)	Apparent gain (+) or loss (-) F= E-D	Net gain (+) or loss (-) G= E-A
50% recommended doses of NPK	302	20	94.16	237.84	289.45	51.61	-12.55
75% recommended doses of NPK	302	30	102.07	239.93	291.88	51.95	-10.12
100% recommended doses of NPK	302	40	127.07	224.93	304.56	79.63	2.56
125% recommended doses of NPK	302	50	137.32	224.68	307.95	83.27	5.95
150% recommended doses of NPK	302	60	146.44	195.56	311.63	116.07	9.63
100% recommended doses of NPK with growth regulators	302	40	149.57	202.43	304.35	101.92	2.35
125% recommended doses of NPK with growth regulators	302	50	153.73	208.27	307.3	99.03	5.30
150% recommended doses of NPK with growth regulators	302	60	161.68	140.32	311.36	171.04	9.36
Control (No fertilizer and growth regulators spray)	302	00	83.00	219.00	287.47	68.47	-14.53

(6.03) respectively. Whereas, application of 150% recommended dose of NPK treatment gave more negative N and P apparent value (37.38) and (70.00) respectively. Application of 150% recommended dose of NPK gave higher positive value of K apparent (171.04). Whereas, 50% of recommended dose of NPK treatment gave minimum value of K apparent value (51.61).

3.3.2 Net gain (+) or loss (-)

The data showed that net gain (+) or loss (-) of NPK nutrient was recorded as control treatment gave more negative value of N and P loss value (9.95) and (3.44) respectively. Whereas, application of 150% recommended dose of NPK gave more positive N and P net gain value (9.32) and (2.31) respectively. Control treatment gave more negative value of K net gain (14.53). Whereas, 150 % recommended dose of NPK treatment gave maximum positive K net gain value (9.63) compare to other treatments.

4. CONCLUSION

The result of this study, concluded that availability of NPK in soil was independent of application of growth regulator while 150% recommended doses of NPK with growth regulators (CCC and Tebuconazole) recorded maximum nutrient uptake by crop in grain and straw it shows an economically viable and ecologically sound option of nutrient management with growth regulator in wheat to extend these benefits of balanced nutrition in enhancing both crop production and soil heath.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/109745