Journal of Advances in Biology & Biotechnology

Volume 27, Issue 9, Page 1291-1301, 2024; Article no.JABB.121967
ISSN: 2394-1081

Impact of Integrated Nutrient Supply System Comprising Inorganic Fertilizers and Organic Manures on Growth and Yield of Wheat (*Triticum aestivum* L.) Crop

Akshay [a++], Mohd Shah Alam [a#*] and Jay Nath Patel [a#]

[a] *Department of Agronomy, School of Agriculture, Abhilashi University, Mandi, H.P. Pin code- 175028, India.*

Authors' contributions

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

Article Information

DOI: https://doi.org/10.9734/jabb/2024/v27i91399

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/121967

Original Research Article

Received: 28/06/2024
Accepted: 02/09/2024
Published: 12/09/2024

ABSTRACT

A field experiment was conducted at the research farm of Abhilashi University Chail chowk Mandi in 2022-23 with the concept of "Studying the influence of integrated nutrient supply system, comprising inorganic fertilizers and organic manures of wheat (*Triticum aestivum* L.) crop". The experiment was laid out in randomized block design with three replications and comprises eight treatments *viz*., T_1-Absolute control, T_2-125% NPK, T_3-100% RDN+ 25% N through vermicompost, T_4-75% RDN +

[++] *M.Sc. Research Scholar;*
[#] *Assistant Professor;*
**Corresponding author: E-mail: mohdshahalam840@gmail.com;*

***Cite as:** Akshay, Mohd Shah Alam, and Jay Nath Patel. 2024. "Impact of Integrated Nutrient Supply System Comprising Inorganic Fertilizers and Organic Manures on Growth and Yield of Wheat (Triticum Aestivum L.) Crop". Journal of Advances in Biology & Biotechnology 27 (9):1291-1301. https://doi.org/10.9734/jabb/2024/v27i91399.*

25% N through vermicompost, T_5-50% RDN + 25% N through vermicompost + Biofertilizer (*Azotobacter)*, T_6-75% RDN + Biofertilizer (*Azotobacter)*, T_7-75% RDN + *Azotobactor* + *PSB (Phosphate Solubilizing Biofertilizer)* and T_8-75% NPK + $ZnSO_4$ @ 25 kg/ha + *Azotobactor.* The highest growth of wheat crop was achieved by adopting nutrient supply system through synthetic fertilizer under treatment T_2-125% NPK which was significantly at par with T_5 50% RDN+ 25% N through vermicompost + 25% N through Biofertilizer (*Azotobactor*), which also proved significantly superior to rest of the treatments. The minimum value of growth parameter was recorded under T_1-Absolute control. Results also revealed that higher yield attributes *viz.* No. of effective tillers, Spike length, No. of spike, Grain per spike, test weight, were recorded under T_2-125% NPK followed by 50% RDN+ 25% N through vermicompost+ 25% N through Biofertilizer (*Azotobactor*) and lowest were recorded under T_1- Absolute control. Yields of crop *viz.* grain yield, straw yield, biological yield was also recorded highest under T_2-125% NPK and lowest were recorded T_1- Absolute control. On the basis of one season study, it can be safely concluded that the application of integrated nutrient supply system 50% RDN+ 25% N through vermicompost+ 25% N through Biofertilizer (*Azotobactor*) gave similar result as 125% NPK in terms of growth and yield.

Keywords: Azotobactor; dry matter; INM; wheat; RDN; vermicompost.

1. INTRODUCTION

"Wheat (*Triticum aestivum* L.) 2n = 42 being a major cereal crop has been cultivated in India and belong to family poaceae, which account for about 60 percent of world's human energy requirement. Wheat is a key staple food that provides around 20 percent of protein and calories consumed worldwide. Wheat contributes more calories (20%) and more protein (11%) to the world's diet than any other food crop. Demand for wheat is projected to continue to grow over the coming decades, particularly in developing in world to feed an increasing population and with wheat being a preferred food, continuing to account for a substantial share of human energy needs in 2050" [1]. It is nutritious, easy to stored, transport and can be processed into various type of food.

"Rapid economic and income growth, urbanization, and globalization are leading to dramatic dietary shifts, especially in Asia as consumer are increasing their consumption of wheat products" [2]. "Wheat production needs to increase to meet the combined growing population and expanding demand by the middle of this century" [3]. "Currently, wheat yield grains are estimated to be 0.9% per year, much less than 1.5% per year, which is required to meet the projected 60% increase in global production needed by 2050" [1]. "A factor which increases the growth and development of wheat crop, plant nutrients are crucial. It is highly responsive to applied nutrient through various sources of integrated nutrient management for proper fertility management optimizing the productivity of wheat crop. The concept of Integrated Nutrient Management should be followed to prevent severe health hazards and to protect the environment. Integrated Nutrient Management refers to combination of all possible sources of nutrients like organic sources inorganic sources and biological sources or components in a judicious way for obtaining an ecologically sound environment and economically optimal farming system. This may be achieved through combined us of all possible sources nutrients and their scientific management for optimum growth, yield and quality of different cropping systems" [4] and [5]. "Continuous application of organic manures year after year improves physical and chemical conditions by providing a favorable soil structure enhance soil cation exchange capacity, increase the quality and availability of plant nutrition increase humus content, and providing the substrate for microbial activity. Combined application of organic and inorganic nutrients to the field not only improves yield and productivity but also tends to preserve the fertility level of soil" [6]. "The INM strategy is focused on preserving the supply of plant nutrition to achieve a certain degree of crop production by cohesively maximizing the benefits of all possible plant nutrition sources, relevant to each crop trend and farming situation" [7]. Integrated use of organic and inorganic nutrient sources helps in gaining sustainable yield and improved soil quality for enhanced production.

"Organic manure inclusion controls nutrient absorption, positively affects growth, enhance soil quality (physical, chemical, and biological) and generates synergistic effects on crops" [8]. "The uptake of nutrients by any crop depends largely on plant output of biomass. However, the accumulation of various nutrients inside the plant system often influences their overall uptake” [9]. Organic matter like FYM has supplied available nutrients to the plants provide favorable soil environment and increase water holding capacity of soil for longer time. Also reported that soil density undergoes greater reduction with the use of FYM than chemical fertilizers. Application of FYM @ 10 and 20 tonnes ha^{-1} increased the grain yield and the total N P and K uptake in wheat crop.

2. MATERIALS AND METHODS

Study area: The current study was carried out at the Agriculture Farm, School of Agriculture, Abhilashi University Mandi, Himachal Pradesh, India, which is situated at 77° East longitude and 31°North longitude and has an altitude of 1500 meters, during the *rabi* season of 2022-23. The soil of the experimental field was slightly acidic in reaction, high in EC, high in organic carbon.

Experiment details: These treatments were replicated three times following randomized block design. The field experiment was carried out eight treatments of integrated nutrient management as T_1 - Absolute control, T_2-125% NPK, T_3-100% RDN+ 25% N through vermicompost, T_4- 75% RDN + 25% N through vermicompost, T_5-50% RDN + 25% N through vermicompost + Biofertilizer (*Azotobactor)*, T_6-75% RDN + Biofertilizer (*Azotobactor)*, T_7-75% RDN + *Azotobactor + PSB (Phosphate Solubilizing Biofertilizer)*, T_8-75% NPK + $ZnSO_4$ @ 25 kg ha^{-1} + *Azotobactor.* Recommended dose of N, P and K for wheat was 120:60:40 kg ha^{-1} respectively. Full quantities of P and K fertilizers were given at the time of sowing. Nitrogen was applied as basal and two splits at first and second irrigation.

Observations recorded: Observations include plant height(cm), no. of tillers(m^{-2}), dry matter accumulation (g m^{-2}), no. of effective tillers(m^{-2}), spike length (cm), no. of spikes (m^{-2}), grains per $spike^{-1}$, test weight(g), Grain yield (q ha^{-1}), straw yield (q ha^{-1}), biological yield (q ha^{-1}) and harvest index (%) of wheat a periodic interval of 30 days.

Statistical Analysis: The data recorded from the field was statistically analysed through the analysis of variance method and treatment means were compared following critical differences (CD) suggested by Gomez and Gomez [10] for significance at 5%. The seed of oat was sown in each plot in second week of November using 100 kg ha^{-1}. Equal amount of water was supplied to every plot at the time of irrigation.

3. RESULTS AND DISCUSSION

Plant height (cm): At 30 days after sowing, the different treatments had no discernible effect on the plant height; however, at 60, 90, and harvest, the plant height differed significantly as a result of the different treatment applications. The integration of T_2 (125% NPK) at 60, 90 DAS and at maturity recorded the maximum plant height, statistically comparable to treatment T_5 [50% RDN + 25% N through vermicompost + 25% N through Biofertilizer (*Azotobactor*)]. On the other hand, treatment T_1 (Absolute control) produced the lowest plant height. This may have happened because the plants were able to absorb more water and nutrients due to the favourable conditions created in the root zone. Consequently, this enhanced the metabolic process and more effectively released the produced carbohydrates into amino acids and proteins. Consequently, the wheat plants displayed morphological alterations, accelerated cell division and elongation, and grew taller. Ghosh et al. [11] observed findings that were similar. Tulasaram and Mir [12].

Number of tillers (m^{-2}): Tillers were determined to be non-significant at 30 DAS during the investigation. But in treatment T_2 (125% NPK), the maximum number of wheat crop tillers—at 60, 90, and at harvest were noted which was statistically comparable, with treatment T_5 [50% RDN + 25% N via vermicompost + 25% N via biofertilizer (*Azotobactor*)]. Conversely, under treatment T_1 (Absolute control), the fewest number of tillers was noted. The result concluded that different nutrient management in wheat crop had positive effect on number of tiller due to higher availability of nutrient in the soil. Panday et al. [13] found a similar result Patil et al. [14].

Dry matter accumulation (g m^{-2}): At 30 days after sowing (DAS), the effect of integrated nutrient management on dry matter accumulation was determined to be non-significant. At 60, 90, and harvest, it was discovered that the integration of treatment T_2 (125% NPK) had the maximum dry matter accumulation. At 60, 90 DAS, and the wheat crop's harvest stage, treatment T_2 was discovered to be on par with treatment T_5 [50% RDN+ 25% N through vermicompost+ 25% N by biofertilizer

(*Azotobacter*)] during investigation. On the other hand, treatment T_1 (Absolute control) showed the least amount of dry matter accumulation. This may be the outcome of plants having more food supplies available for synthesis when they have more tillers and height. Increased accessibility and availability of nourishment could be the reason for this. These results are in good agreement with those of Singh and Yadav [15] and Fazily et al. [16].

Table 1. Initial chemical parameters of the experimental soil

Sr. No.	Particular	Content
1	pH (1:2.5, soil: water suspension)	5.4
2	Electrical conductivity (dS m^{-1}) (1:2.5 soil: water extract)	0.30
3	Organic carbon (%)	0.32
4	Available N (kg/ha)	240
5	Available P (kg/ha)	16.12
6	Available K (kg/ha)	230

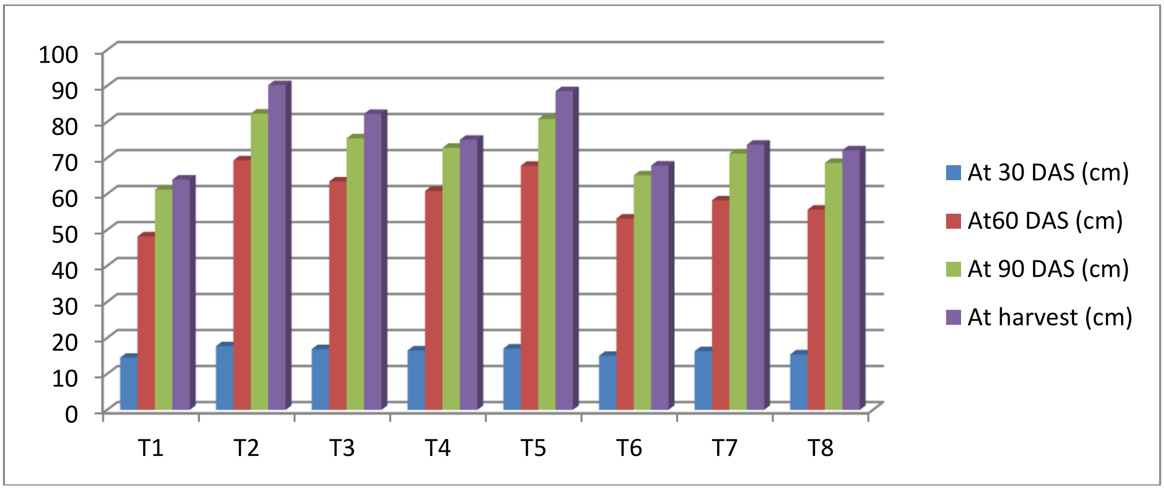

Fig. 1. Bar graph showing the effect of integrated nutrient management on plant height (cm) of wheat crop

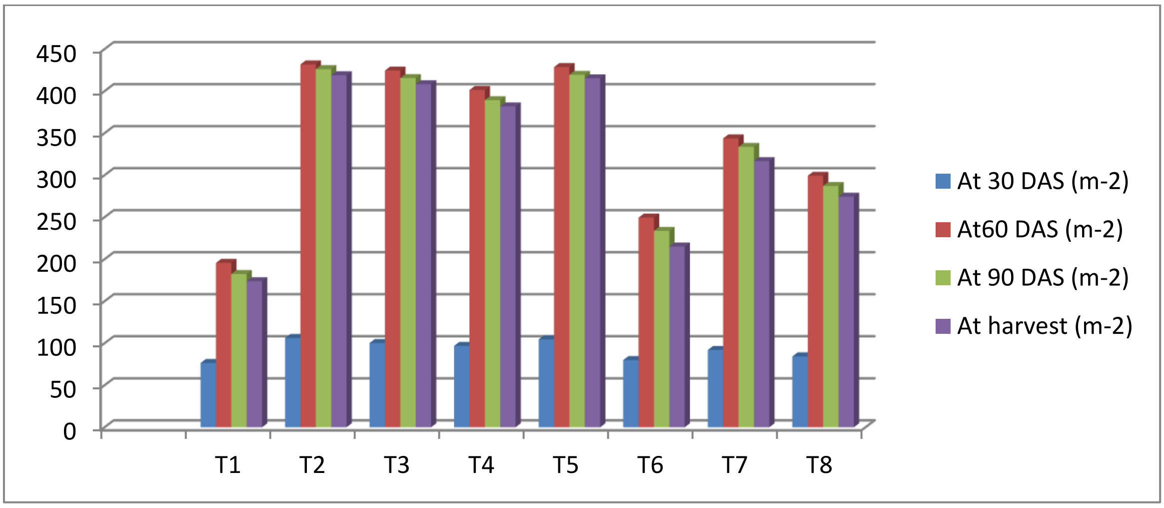

Fig. 2. Bar graph showing the effect of integrated nutrient management on number of tillers (m^{-2}) of wheat crop

Table 2. Effect of integrated nutrient management on plant height (cm) of wheat crop

Sr. No	Treatments	Plant height (cm)			
		At 30 DAS	At 60 DAS	At 90 DAS	At Harvest
T_1	Absolute control (No use of fertilizer and chemicals)	14.51	48.21	61.21	63.98
T_2	125% NPK	17.68	69.33	82.33	90.23
T_3	100% RDN+ 25% N through vermicompost	16.88	63.45	75.45	82.22
T_4	75% RDN+ 25% N through vermicompost	16.52	60.83	72.83	75.03
T_5	50% RDN+ 25% N through vermicompost+ 25% N through Biofertilizer (*Azotobacter*)	17.05	67.83	80.83	88.55
T_6	75% RDN+ 25% N through biofertilizer (*Azotobacter*)	15.04	53.17	65.17	67.87
T_7	75% RDN + *Azotobacter* + PSB (Phosphate Solubilizing Biofertilizer)	16.32	58.20	71.20	73.66
T_8	75% RDN + $ZnSO_4$ @ 25 kg/ha+ *Azotobacter*	15.42	55.62	68.62	72.11
	SE (m)	0.75	1.04	1.18	1.46
	C.D.	NS	3.21	3.61	4.49

Table 3. Effect of integrated nutrient management on number of tillers (m^{-2}) of wheat crop

S.N.	Treatments	Number of tillers (m^{-2})			
		At 30DAS	At 60 DAS	At 90 DAS	At Harvest
T_1	Absolute control	76.53	173.78	195.64	182.32
T_2	125% NPK	106.26	418.82	431.73	426.11
T_3	100% RDN+ 25% N through vermicompost	100.24	408.15	424.45	415.42
T_4	75% RDN+ 25% N through vermicompost	96.87	381.77	401.36	389.24
T_5	50% RDN+ 25% N through vermicompost+ 25% N through Biofertilizer (*Azotobacter*)	104.62	415.21	428.58	419.36
T_6	75% RDN+ 25% N through biofertilizer (*Azotobacter*)	79.98	215.03	249.47	233.64
T_7	75% RDN + *Azotobacter* + PSB (Phosphate Solubilizing Biofertilizer)	91.96	316.65	343.71	333.58
T_8	75% RDN + $ZnSO_4$ @ 25 kg/ha+ *Azotobacter*	84.36	274.34	299.27	287.09
	SEm±	7.51	2.30	1.69	2.85
	C.D	NS	7.05	5.18	8.73

Table 4. Effect of nutrient management dry matter accumulation of wheat crop

Sr. No	Treatments	At 30 DAS	At 60 DAS	At 90 DAS	At Harvest
T1	Absolute control (No use of fertilizer and chemicals)	79.12	270.98	440.26	680.41
T2	125% NPK	120.55	439.71	690.18	944.40
T3	100% RDN+ 25% N through vermicompost	111.96	414.93	663.33	912.18
T4	75% RDN+ 25% N through vermicompost	104.56	385.07	611.48	882.50
T5	50% RDN+ 25% N through vermicompost+ 25% N through Biofertilizer (*Azotobacter*)	116.84	421.24	686.68	933.67
T6	75% RDN+ 25% N through biofertilizer (*Azotobacter*)	85.07	330.18	575.72	805.23
T7	75% RDN + *Azotobacter* + PSB (Phosphate Solubilizing Biofertilizer)	97.53	370.84	600.27	844.55
T8	75% RDN + $ZnSO_4$ @ 25 kg/ha+ *Azotobacter*	91.39	360.52	590.59	826.07
	C.D	NS	20.372	20.142	29.239
	SEm±	9.351	6.652	6.577	9.547

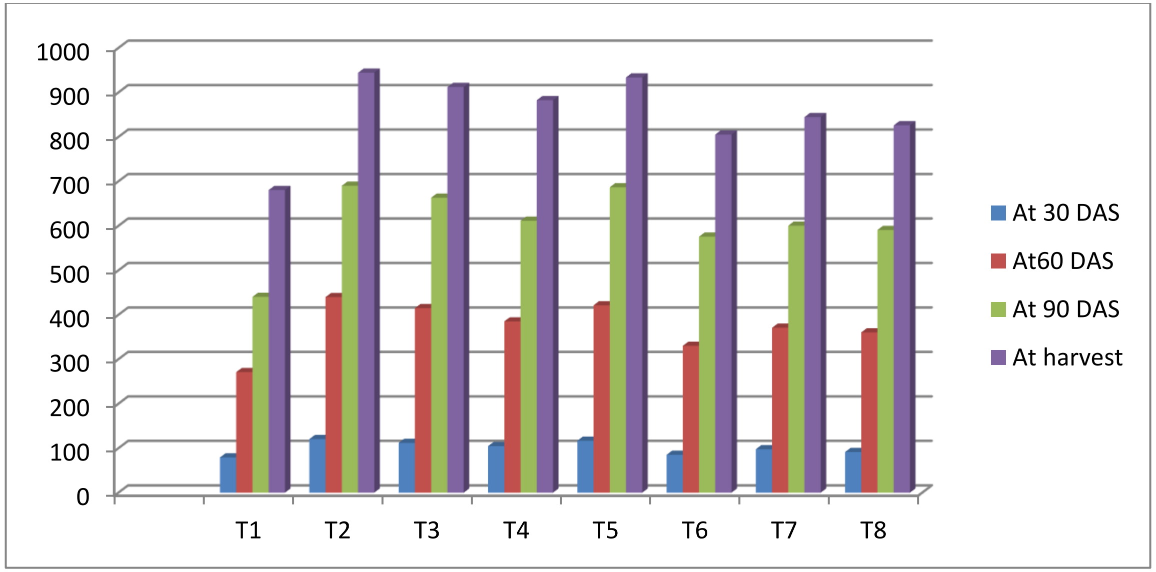

Fig. 3. Bar graph showing the effect of nutrient management dry matter accumulation of wheat crop

Yield studies:

No. of effective tillers (m^{-2}): Among the various nutrient management treatments, treatment T_2 (125% NPK) produced the maximum number of productive tillers, and it was statistically comparable to treatment T_5 [50% RDN + 25% N via vermicompost + 25% N via biofertilizer (*Azotobacter*)]. On the other hand, treatment T_1 (Absolute control) showed the fewest effective tillers due to lack of nutrient supply through organic and inorganic fertilizer. An appropriate nutrition supply may lead to increased interception of photosynthetically active radiations and dry matter accumulation, which would account for much higher effective tiller density in high nutritional levels. More productive tillers were produced in nutrient-rich treatments due to increased tillering and better plant development brought about by higher nutrition. Higher nutrient levels and higher tiller density have also been reported by other researchers Nehra et al. [17] and Reddy et al. [18].

Spike length (cm): Table 5 and Fig. 4 shows that wheat crop with the longest spike length was observed in treatment T_2 (125%NPK), which was similar to treatment T_5 [50% RDN + 25% N via vermicompost + 25% N via biofertilizer (*Azotobacter*)]. On the other hand, wheat crop spike length was lowest in treatment T_1 (absolute control). This may be the result of the plant being able to absorb the maximum amount of NPK from the organic source thanks to its well-developed root system. Second, adding chemical fertilizer lengthens the spike and is positively connected with the yield of grains and straw. It also increases the quantity of photosynthesis generated and the transfer of the source to the sink, leading to an increase in the length of spikes (cm). Corresponding findings have also been published by Verma et al. [19] and Jaga and Upadhyay [20].

Grain spike^{-1}: The data from the Table 5 and Fig. 4 shows that different nutrient management treatments had no significant effect on grain per spike during the investigation. However, treatment T_2 (125% NPK) had showed the highest number of grains per spike but under treatment T_1 (Absolute control) had lowest number of grains spike^{-1}. This could be because the number of grains per spike is one of the specific traits of a crop variety, and the number of grains per spike was less affected by changes in the nutrient supply or an increased nutrient supply. Verma et al. [19] and Singhal et al. [21] have also published similar results.

Test weight (g): According to the information in Table 5 and Fig. 4, there was no discernible effect of the various nutrient management strategies on grain weight during the study. However, among the various treatments, treatment T_2 (125% NPK) had the highest test weight. Nonetheless, treatment T_1 (Absolute control) showed the lowest 100- grain weight of wheat crop. During the crop's growth period, a higher dose of NPK was administered, which raised the test weight but not significantly.

Grain yield (q ha^{-1}): Wheat crops treated with integrated nutrient management strategies demonstrated a considerable impact on grain yield, as seen by Table 5 and Fig. 5. The treatment T_2 (125% NPK) produced the highest grain yield of the wheat crop, which was statistically comparable to treatment T_5 [50% RDN + 25% N via vermicompost + 25% N via biofertilizer (*Azotobacter*)]. However, treatment T_1 (Absolute control) produced the lowest grain yield.

The main essential nutrient provided to plants is NPK, which is essential to photosynthesis. More nitrogen was added, increasing yield, as a result of the high dose of NPK, which sped up photosynthesis and generated a significant amount of dry matter and assimilates that were transported to fill the seeds. It is also well known that higher fertilizer application amounts lead to improvements in the capacity and intensity of soil nitrogen supply. Thus, higher fertility utilization and enhanced nutrient uptake promoted yield characteristics and plant development, which in turn promoted the production of grains and straw. The observations supported the findings of Wang et al [22], Hadis et al. [23] and Sheikh and Dwivedi [24].

Straw yield (q ha^{-1}): When wheat was treated with integrated nutrition management strategies, the results were shown in Table 5 and Fig. 5, which indicated a considerable impact on straw yield. The treatment T_2 (125% NPK) produced the highest straw yield of wheat crop, which was statistically comparable to treatment T_5 [50% RDN + 25% N via vermicompost + 25% N via biofertilizer (*Azotobacter*)]. Conversely, the treatment T_1 (Absolute control) produced the lowest straw yield. The lowest straw yield was seen in the control group because the soil was unable to provide the plants with necessary nutrients due to the lack of applied fertilizers. Reduced nutrient availability, particularly in the early phases, caused the crop to grow slowly at initially and had poor root formation. The crop growing season was marred by this poor growth, which led to a much-decreased yield of straw. Similar findings were also reported by Shahi et al. [25] and Reena et al. [26] who showed that higher fertilizer dose treatments led to higher straw yields.

Biological yield (q ha^{-1}): Among the various treatments, T_2 (125% NPK) produced the highest biological yield of wheat crop, which was statistically comparable to treatment T_5 [50% RDN + 25% N via vermicompost + 25% N via biofertilizer (*Azotobactor*)]. In contrast, treatment T_1 (Absolute control) produced the lowest biological yield. Increasing NPK application resulted in taller plants, higher grain output, more tillers per unit, and total dry matter, all of which boosted biological yield. Numerous studies have shown that biological yield rose when the NPK rate increased [27] and Desai et al. 2015.

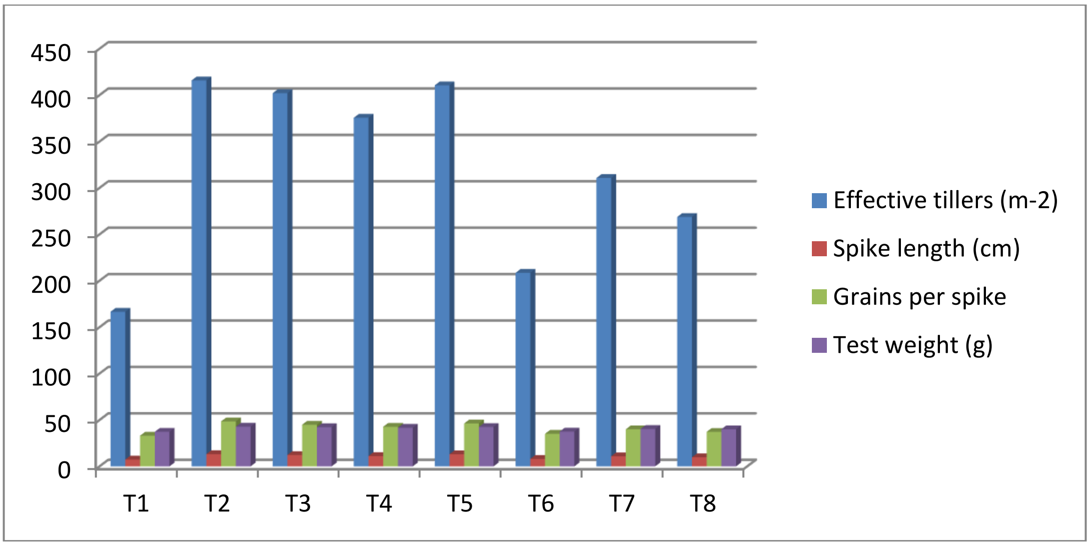

Fig. 4. Bar graph showing the effect of integrated nutrient management on Number of effective tillers (m^{-2}), spike length (cm), grain per spike and test weight (g) of wheat crop

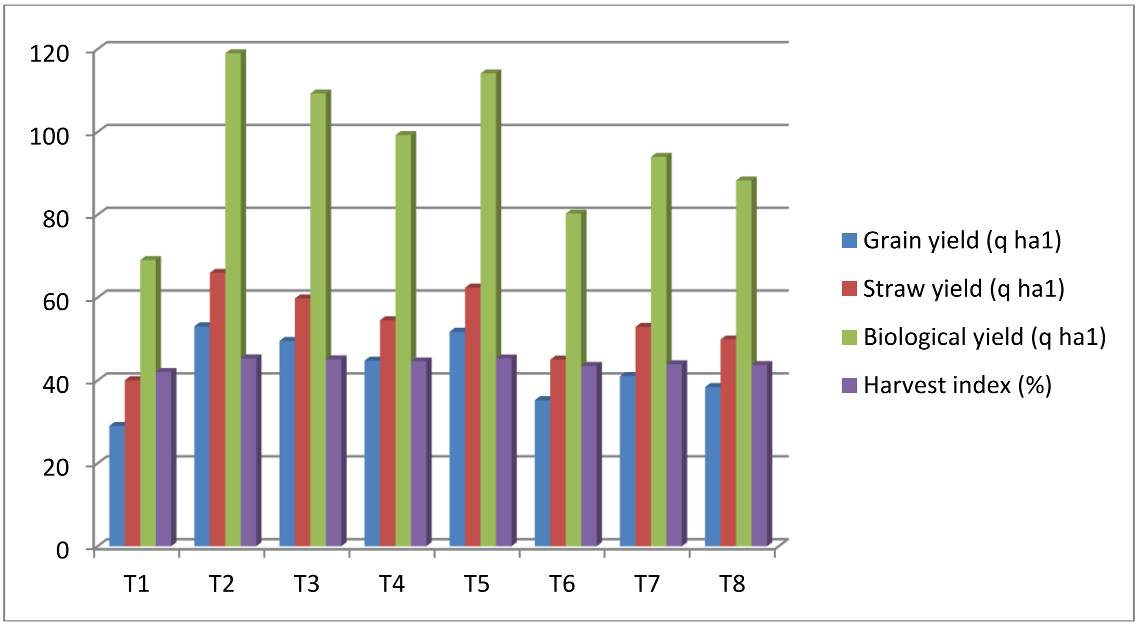

Fig. 5. Bar graph showing the effect of nutrient management on grain yield, straw yield, biological yield and harvest index of wheat crop.

Table 5. Effect of integrated nutrient management on Number of effective tillers (m^{-2}), spike length (cm), grain per spike and test weight (g) of wheat crop

Sr. No.	Treatments	No. of effective tillers (m^{-2})	Spike length (cm)	Grains per spike	Test weight (g)
T_1	Absolute control	166.57	7.38	33.10	37.30
T_2	125% NPK	415.88	13.20	48.53	42.78
T_3	100% RDN+ 25% N through vermicompost	402.18	12.25	44.90	42.25
T_4	75% RDN+ 25% N through vermicompost	375.66	11.12	42.70	41.60
T_5	50% RDN+ 25% N through vermicompost+ 25% N through Biofertilizer (*Azotobacter*)	410.62	13.05	46.30	42.47
T_6	75% RDN+ 25% N through biofertilizer (*Azotobacter*)	208.58	8.09	35.13	37.53
T_7	75% RDN +*Azotobacter* + PSB (Phosphate Solubilizing Biofertilizer)	310.81	10.85	40.01	40.37
T_8	75% RDN + $ZnSO_4$ @ 25 kg/ha+ *Azotobacter*	268.75	9.81	37.17	40.00
C.D.		15.397	0.493	NS	NS
SEm±		5.027	0.161	4.132	1.516

Table 6. Effect of nutrient management on grain yield, straw yield, biological yield and harvest index of wheat crop

Sr. No	Treatments	Grain yield (q ha^1)	Straw yield (q ha^1)	Biological yield (q ha^1)	Harvest index (%)
T1	Absolute control	29.01	40.04	69.05	42.01
T2	125% NPK	53.05	65.95	119.00	45.33
T3	100% RDN+ 25% N through vermicompost	49.51	59.78	109.29	45.09
T4	75% RDN+ 25% N through vermicompost	44.76	54.49	99.25	44.57
T5	50% RDN+ 25% N through vermicompost+ 25%N through Biofertilizer (*Azotobacter*)	51.74	62.40	114.14	45.30
T6	75% RDN+ 25% N through biofertilizer (*Azotobacter*)	35.24	45.03	80.27	43.50
T7	75% RDN+ 25% N through biofertilizer *Azotobacter* + PSB (Phosphate Solubilizing Biofertilizer)	41.07	52.90	93.97	43.90
T8	75% RDN + $ZnSO_4$ @ 25 kg/ha+ 25% N through biofertilizer *Azotobacter*	38.40	49.87	88.27	43.70
	SEm±	0.743	1.376	1.933	0.902
	C.D	2.275	4.213	5.92	NS

Harvest index (%): The results indicate that treatment T_2 (125% NPK) produced the highest harvest index, while treatment T_1 (Absolute control) produced the lowest harvest index. Seed development is slowed down and grows smaller when the harvest index is low because fewer assimilates are being translocated from the source to the sink. Greater assimilation of the grains from the source is indicated by a high harvest index, which also signifies better fullness and development. Plant dry matter and grain weight have a strong correlation with the harvest index; both are ultimately dependent on the availability and uptake of nutrients, especially nitrogen. To a limited degree, growth and development are positively correlated with nitrogen levels. In addition, Pandey et al. [28] describe similar results Tayebeh et al. [29][30].

4. CONCLUSION

The summary given above leads to the following conclusions: The growth and yield of the wheat crop were positively impacted by the combined application of inorganic fertilizer and organic source. The implementation of an integrated nutrition management treatment, such as 50% RDN+ 25% N through vermicompost+ 25%N through Biofertilizer (*Azotobactor*), may lead to an increase in wheat yield.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Akshay Kumar here by declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

ACKNOWLEDGEMENT

I, Akshay Kumar would like to express my sincere gratitude to everyone who helped to make this research work successful. Above all, I would want to express my gratitude to Dr. Mohd Shah Alam, my major adviser, for his invaluable advice, encouragement and support during this entire study. The course of this research has been greatly influenced by their knowledge and helpful guidance. Additionally, I am thankful to the Dr. Jay Nath Patel for their valuable helps. The Department of Agronomy, School of Agriculture. Abhilashi University is acknowledged by the authors for providing the required field and laboratory facilities. I want to express my heartfelt appreciation to everyone. who has provided thoughtful feedback on how to improve the manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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