Impact of Organic Manure, Inorganic Fertilizers and Bioinoculants on production and economics of wheat(*Triticumaestivum* L.)

Abstract

Field trials were undertaken to investigate the impact of integrated nutrient management on wheat yield and economic aspects during the Rabi season of 2021-22 and 2022-23. The experimentation took place at the student's instructional farm of Chandra Shekhar Azad University of Agriculture & Technology in Kanpur. The study encompassed 11 treatment combinations, organized in a randomized block design with three replications. These treatments involved varying combinations of inorganic fertilizers, organic manure, and biofertilizers. The cultivation of wheat variety HD-2967 was carried out in accordance with the suggested agronomic practices.Based on the outcomes derived from the investigation, it can be deduced that among the various productivity parameters, the treatment labeled as T_{10} [100% NPK + S_{40} + Zn_5 + Fe_{10} + *Azotobacter* + *PSB* + 5 ton FYM] exhibited the highest grain yield of 48.60 and 49.93 quintals per hectare, straw yield of 63.15 and 67.53 quintals per hectare, and biological yield of 111.75 and 117.46 quintals per hectare across both years of experimentation.For economic factors, the treatment T10 also yielded the highest gross returns of ₹ 1,40,190 and ₹ 154,632 during the first year (2021-22) and second year (2022-23) of the experiment, respectively. Moreover, the treatment T_7 [100% NPK + Zn_5] showcased the maximum benefit-cost ratio (B:C ratio) of 2.26 and 2.39. It is noteworthy that the highest costs of cultivation were observed in the treatment T_{10}, amounting to ₹ 53,805 in the first year and ₹ 55,561 in the second year. This treatment encompassed a combination of 100% NPK, S_{40}, Zn_5, Fe_{10}, *Azotobacter,PSB,* and 5 tons of FYM.

Key Words: *Azotobacte*r,Economics, FYM, Phosphorous, PSB, Wheat and Yield.

Introduction

Wheat, a nourishing winter crop rich in energy, constitutes approximately 35% of the total food grain production in the nation. Cultivated in 124 countries worldwide, Wheat (*Triticumaestivum* L.) spans an extensive land area of approximately 215 million hectares and yielded 734.50 million metric tons of grain during the 2019-20 period (Anonymous, 2020). Since the onset of the green revolution in 1967, the area under wheat in India has expanded, as has production and productivity. Wheat area grew from 12.8 million hectares in 1966-67 to 31.45 million hectares in 2019-20. During this time, output climbed from 11.4 to 107.59 mt, and productivity increased from 887 to 3421 kg ha^{-1}**(Anonymous, 2020).**

One of the main cereal crops, wheat (*Triticumaestivum* L.), is grown all over the world in various conditions and has a special protein that is ingested by humans **(Abedi*et al.*, 2010).** According to **Rueda-Ayala *et al.* (2011),** wheat is the cereal that is most important as a primary source of carbs and protein for both humans and animals. It contains starch (60-90%), protein (11-16.5%), fat (1.5-2%), inorganic ions(1.2 – 2%) and vitamins (B complex and vitamin E).

The output of food grains has recently stalled or even decreased for both wheat and rice harvests **(Dawe and Dobermann, 1999),** and there is a significant difference between the intended and actual yields **(Pathak *et al.*, 2003).** There are many causes for the low productivity of wheat, but imbalanced and excessive fertilizer application is one of the main ones. Other causes include changes in the physico-chemical composition of the soil, a depletion and reduction in the bioavailability of soil nutrients, a lack of good groundwater, the accumulation of pests, and the attack of various diseases of wheat, all of which have a significant impact on the yield and quality of wheat. Chemical fertilizers should never be applied carelessly because doing so depletes the soil's biological capacity and reduces soil fertility and crop productivity **(Parewa*et al.* 2014).** Therefore, integrated nutrient management encourages the balanced and concurrent application of organic manure, inorganic fertilizer, and bio-inoculants in order to maintain or alter soil fertility and plant nutrient supply to an ideal level for maintaining targeted crop output **(Rakshit*et al.* 2008).**

Nitrogen (N) plays a critical role in determining wheat yield. The capacity of wheat varieties to efficiently utilize nitrogen has gained prominence as it offers the potential to reduce nitrogen fertilizer usage while maintaining yield levels. The demand for nutrients, particularly nitrogen, is substantial for the growth and yield of wheat, a significant cereal crop **(Mandal *et al.*, 1992;Krylov and Pavlov, 1989).** Enhancing wheat production necessitates a careful consideration of factors such as nitrogen rate, type of nitrogen, and timing of application **(Garrido-Lestache*et al.*, 2005).** Notably, certain studies indicate that nitrogen fertilization leads to an increase in protein content in flour, thereby elevating the levels of gliadins and glutenin**(Dupont and Altenbach, 2003)**

According to **Ziadi*et al.* (2008),** phosphorus is crucial for improving seed maturity and seed development. Phosphorus is an important component of several essential processes, including photosynthesis, the conversion of sugar to starch, the generation of proteins and nucleic acids, the fixation of nitrogen, and the production of oil. In plants, it is also a component of every metabolic cycle **(Mehrvarz and Chaichi, 2008).**

Due to its active role in the biochemical processes of the plant, such as the activation of numerous enzymes, enhancement of protein, carbohydrate, and fat concentration, development of drought tolerance, and development of resistance to frost, lodging, pest, and disease assault, potassium (K+) is of remarkable relevance. As a result, potassium was referred to as a "quality element" and was seen as crucial to crop production (Moussa, 2000). Therefore, it is essential to develop fertilizer technology that makes it easier to utilize NPK in the right mix to increase wheat production **(Jabbar*et al.*, 2009).**

Due to its necessity in numerous enzymes and crucial involvement in DNA transcription, zinc is regarded as an essential element for the growth of wheat. According to reports, pollen contains a significant amount of zinc, most of which is converted to seeds only during seed germination and is applied to promote grain formation **(Choudhary *et al.*, 2007).**

Even though certain crops require more sulphur than others do, in general, crops with lower sulphur requirements, such as cereals, begin to experience more and more sulphur deficiency symptoms. In addition, boosting sulphur fertilisation has been shown to improve the biological value of proteins and the baking qualities of wheat **(Marschner, 1997; Jarvan*et al.*, 2006).**

A well-considered integration of chemical fertilizers and farmyard manure (FYM) yields multiple benefits by improving the soil's physical, chemical, and biological attributes, ultimately leading to heightened crop productivity **(Sharma *et al.*, 2007).** The utilization of organic manures has the potential to augment the inherent nutrient content within the soil, thereby amplifying the efficacy of subsequent fertilizer applications **(Sawrup, 2010).** This combination approach not only optimizes nutrient availability but also contributes to the overall health and fertility of the soil, fostering sustainable agricultural practices

An integrated approach to nutrient provisioning for plants, encompassing a balanced utilization of chemical fertilizers, organic manures, and bio-fertilizers, is of pressing importance. The capabilities of Azotobacter in fixing nitrogen and solubilizing phosphate, coupled with their potential to synthesize growth-promoting compounds, have the potential to enhance crop performance significantly. Azotobacter, in conjunction with carefully calibrated nitrogen applications, profoundly enhances the uptake of phosphorus and potassium by plants. However, due to limitations in its ability to establish a strong presence in wheat's rhizosphere, direct application is recommended. Inoculating agricultural crops with a tailored bacterial strain holds promise as it can expedite plant growth effectively. Furthermore, the solubilization of applied phosphates and the conversion of fixed soil phosphorus by phosphate solubilizing bacteria (PSB) have been empirically proven to augment crop yields **(Panhwar *et al.*, 2014).** This emphasizes the role of microbial intervention in sustainable agricultural practices, enhancing nutrient availability and promoting crop productivity

Availability of iron plays a critical role in wheat crop productivity and economics. Ensuring an adequate supply of iron to wheat plants is essential for chlorophyll formation, photosynthesis, nutrient uptake, stress resistance, grain development, and overall yield. Iron deficiency can lead to decreased yield, lower grain quality, and additional costs associated with corrective measures. Balancing the costs of iron fertilizer application with the potential economic benefits of improved yield and grain quality is an important consideration for wheat farmers. (**Saquee *et al.*, 2023)**

Methods

Experimental Site

The study took place in the winter cropping seasons of 2021-22 and 2022-23 at the student's instructional farm located in Kanpur Nagar, Uttar Pradesh. The farm, situated in the main campus of C.S.A. University of Agriculture and Technology, was equipped with well-leveled fields and irrigation through a tube well. Positioned in the western northern region of Kanpur city, the farm falls within the sub-tropical zone of the fifth agroclimatic zone, known as the central plain zone

EdaphicCondition

The soil displayed adequate moisture, effective drainage, and consistent flat terrain. The soil type in the designated research area originated from alluvial deposits, possessed a sandy loam texture, and had a mildly alkaline pH.Analytical data of the experimental soil and method employed in the estimation was given in the Table-1

Table 1: Analytical data of the experimental soil (pre-sowing)

S. No.	Soil characters	Value		Method employed
		2021-22	**2022-23**	
1.	pH (1:2.5 soil water suspension)	8.14	8.15	Glass electrode pH meter **(Jackson, 1973)**
2.	EC (dsm^{-1}) (1:2.5 soil water suspension)	0.45	0.46	Conductivity bridge **(Jackson, 1973)**
3	Mechanical analysis			Hydrometer Method (**Bouyoucos, 1962**)
i	Sand (%)	60.92	60.40	
ii	Silt (%)	21.71	22.21	
iii	Clay (%)	17.37	17.29	
iv	Texture	Sandy loam	Sandy loam	
4.	Organic carbon (%)	0.35	0.36	Chromic acid digestion **(Walkley and Black, 1934)**
5.	Available N (kg ha^{-1})	178.16	180.56	Alkaline permanganate method **(Subbiah and Asija, 1956)**
6.	Available P (kg ha^{-1})	13.04	13.21	Olsen's calorimetrically method **(Olsen *et al.*, 1954)**
7.	Available K (kg ha^{-1})	129.54	132.42	Flame photometer Ammonium acetate extract **(Hanaway and Heidel, 1952)**
8.	Available S (kg ha^{-1})	15.98	16.02	Turbidimetric (0.15 % $CaCl_2$) method **(Chensin and Yien, 1950)**
9.	Available Zn (mg kg^{-1})	0.420	0.421	DTPA extraction (AAS) **Lindsay and Norvell (1978)**
10.	Available Fe (mg kg^{-1})	10.38	10.41	DTPA extraction (AAS) **Lindsay and Norvell (1978)**

Detail of treatments and design

Eleven different treatment combinations involving strategies for nutrient management were employed. These included inorganic fertilizers such as Urea, DAP, MOP, elemental sulphur, zinc oxide, and iron oxide, along with organic manure (FYM) and bio fertilizers like *Azotobacter* and *PSB*. Experiment was laid out in randomized block design with three replications.

Table -2: detail of the treatment combinations:

S. No.	Code	Treatment combinations
1.	**T_1**	Control
2.	**T_2**	100% NPK
3.	**T_3**	100 % NPK + 5 ton FYM
4.	**T_4**	100 % NPK + PSB + *Azotobacter*
5.	**T_5**	125 % NPK + *PSB* + *Azotobacter* + 5 ton FYM
6.	**T_6**	100 % NPK + S_{40}
7.	**T_7**	100 % NPK + Zn_5
8.	**T_8**	100 % NPK + S_{40} + Zn_5
9.	**T_9**	100 % NPK + S_{40} + Zn_5 + Fe_{10}
10.	**T_{10}**	100 % NPK + S_{40} + Zn_5 + Fe_{10} + *Azotobacter* + *PSB* + 5 ton FYM
11.	**T_{11}**	125 % NPK

Agronomic practices

To ensure optimal moisture levels for healthy seedling growth, pre-sowing irrigation (known as Paleva) was conducted at the crop production trial site. The field preparation involved a single ploughing using a tractor-mounted chisel plough followed by two cultivator passes. For fertilization, half of the nitrogen quantity was applied along with the complete phosphorus and potassium doses. This served as a foundation for incorporating urea, DAP, and MOP. The remaining half of the nitrogen was split into two portions and applied at 30 and 55 days after seeding (DAS). Wheat variety HD-2967 seeds were manually sown at a depth of 2-3 cm in rows, maintaining a uniform row spacing of 22.5 cm to ensure consistent plant distribution. Additional activities included the application of FYM and the treatment of the soil with Azotobacter and PSB

Harvesting and threshing: The crops were harvested as they ripened and sun-dried. A separate bundle was made and weighed for each plot. After drying, the crop was threshed by hand.

Collection of data

Grain yield

Following the threshing process, the yield of grains from each plot was individually measured, converted to quintals per hectare, and then documented.

Straw yield

Upon deducting the grain yield of the specific plot from the overall biological yield, the resultant yield was recalculated to obtain the yield in cents per hectare, and this adjusted yield was subsequently recorded.

Biological yield (q ha^{-1})

Both the grain yield and straw yield were combined to determine the biological yield. The calculation of the biological yield was performed using the provided formula.

$$\textbf{Biological yield = Grain yield + Straw yield}$$

Harvest index(%):

The yield, expressed as a percentage, was determined by considering the grain recovery in relation to the total dry matter. This calculation was carried out using the following formula:

$$\textbf{Harvest Index (\%) = [Seed Yield (q ha}^{-1}\textbf{) / Biological Yield (q ha}^{-1}\textbf{)] x 100}$$

Economics:

The economic analysis of various treatments was conducted using the average yield (comprising both seeds and straw) from the years 2021-22 and 2022-23 as the basis.

Cost of cultivation (₹ ha^{-1}):

The cost of cultivation was calculated using the input rates established on the farm. The expenses associated with each treatment were computed individually. The combined cost of cultivation per hectare (₹ ha^{-1}) was determined by considering all the expenditures related to cultivation, and the additional variable costs incurred due to treatments were added (including the interest on working capital), resulting in the total cost of cultivation.

Gross return (₹ ha^{-1}):

The computation involved deriving revenue from both the grains and straw, considering prevailing market rates. The chickpea crop's yield was translated into a gross return in rupees per hectare, taking into account the current market value of the produce.

$$\textbf{Gross return } (₹\,\textbf{ha}^{-1}) = \textbf{ Total income from grain and straw yield}$$

Net return (₹ ha^{-1})

The net income for each treatment was divided by the corresponding cultivation cost, resulting in the calculation of the cost-benefit ratio. The net return was calculated using the formula as follows:

$$\textbf{Net return (₹ ha}^{-1}\textbf{) = Gross return (₹ ha}^{-1}\textbf{) - Cost of cultivation (₹ ha}^{-1}\textbf{)}$$

Benefit Cost ratio (B:C)

The cost-benefit ratio was determined by dividing the net income of each treatment by its corresponding cultivation cost. This calculation was conducted using the provided formula

$$\boldsymbol{Benefit{:}\,cost\ ratio} = \frac{\boldsymbol{Net\ Return}\ (₹\,\boldsymbol{ha^{-1}})}{\boldsymbol{Cost\ of\ cultivation}\ (₹\,\boldsymbol{ha^{-1}})}$$

Statistical analysis:

The growth parameters and yields were documented and assessed in accordance with the methodology outlined by Gomez and Gomez in 1984. Statistical analysis was performed using a significance level of 5% to interpret any noteworthy differences.

Result and Discussion

Productivity Parameters

The data presented in Table-3 and Table-4 vividly illustrate that the application of NPK, Zinc, Iron, Sulphur, FYM, *Azotobacter*, and *PSB* significantly enhances various productivity parameters, including grain yield (q ha^{-1}), straw yield (q ha^{-1}), and biological yield (q ha^{-1}). Grain yield ranged from 18.87 to 49.27 q ha^{-1}, straw yield varied from 29.15 to 65.34 q ha^{-1}, and biological yield varied from 48.02 to 104.63 q ha^{-1} in a combined analysis. During the second year (2022-23) of experimentation, the treatment T_{10} [100% NPK + S_{40} + Zn_5 + Fe_{10} + *Azotobacter* + *PSB* + 5 ton FYM] exhibited the highest grain yield (49.93 q ha^{-1}), straw yield (67.63 q ha^{-1}), and biological yield (114.61 q ha^{-1}). Conversely, the treatment T_1 [control] recorded the lowest grain yield (17.90 q ha^{-1}), straw yield (26.87 q ha^{-1}), and biological yield (44.77 q ha^{-1}) during the first year (2021-22).The substantial increase in seed and stover yields due to adequate nutrient supply can be attributed primarily to the combined effect of enhanced spikelet ear^{-1}, grain ear^{-1}, and 100-grain weight (gm). This improvement in translocation of photosynthates from source to sink contributes to an overall increase in yield. The heightened productivity under proper nutrient supply results from improved yield attributes, ultimately translating to increased grain yield. Grain, straw and biological yield of wheat significantly increased due to FYM application over their controls. Application of *Azotobacter* and *PSB* further increased grain & straw yield of wheat significantly over without application of *Azotobacter* and *PSB.* Inoculation of *Azotobacter* and *PSB* further increased grain & straw yield of wheat significantly over without inoculation. This may be due to soil treatment with bio inoculum that fixes atmospheric nitrogen and increases the supply of other nutrients to plants, ultimately increasing the yield of grain and wheat straw. These results are also supported by Singh and **Jat (2016), Kumar *et al.* (2022)** and **Sachan *et al.* (2022)** complex application of nutrients did not significantly affect yield indices. Harvest index ranged from a total of 39.34% to 41.04%. The highest harvest index (43.49%) was associated with T_{10} [100 % NPK + S_{40} + Zn_5 + Fe_{10} + *Azotobacter* + *PSB* + 5 ton FYM] treatment during the first year of the experiment (2021–22). At the same time, the lowest yield indicator (38.69%) was recorded for the T_1 [control] strain in the second year of the experiment. These results are also consistent with **Verma *et al.* (2022), Sirohiya *et al.* (2022)** and **Kumar *et al.* (2022).**

Economics

Economic viability depends on profit or loss. Any practice that is economical and feasible must strike a significant balance of costs. Developed to ensure net profit and profitability at a B:C ratio. While studying the economics of wheat cultivation during the two years of the experiment, all economic parameters such as gross margin, net profit and cost-benefit ratio excluding the cost of cultivation were NPK, Zn, iron, sulphur, FYM, *Azotobacter* and *PSB*.From the data extracted from the Table 4 and Table 5 it can be concluded that the maximum gross return (₹ 154632) was recorded when processed according toT_{10} [100 % NPK + S_{40} + Zn_5 + Fe_{10} + *Azotobacte*r + *PSB*+

5 ton FYM]during the second year (2022-23) experiment. During the first year (2021-22) of experiment a minimum gross profit (₹ 54162) was recorded for the T_1 [control]option.The highest net profit (₹ 100712) was recorded forT_7 [100% NPK + Zn_5] treated in the second year of experimentation of the trail (2022-23). During the first year of experiment (2021-22), minimal net profit (₹ 23511) was recorded for the T_1 [control]treatment. Similarly, Maximum B:C ratio (2.39) was recorded with theT_7 [100% NPK + Zn_5] treatment during the second year of experiment (2022-23).The minimum B:C ratio (0.76) was recorded in the treatment T_1 [control] during the first year (2021-22) of experimentation.In the similar pattern, in case of cost of cultivation it can concluded that the maximum cost of cultivation (₹ 55661) was found in the treatment T_{10} [100%NPK + FYM + S_{30}+ Zn_5 +*Azotobacter* + PSB] during the second year of experimentation and minimum cost of cultivation (₹ 30651) was recorded in the treatment T_1 [control] during the first year (2021-22) of experimentation.In contemporary agriculture, prioritizing maximum profit over just higher yield is economically sensible. The true evaluation of various treatments depends on their economic feasibility. Notably, the diverse application of inorganic, organic, and bio-inoculant nutrients resulted in significant variations in both costs and gross returns. These disparities ultimately impacted the net return and the benefit-to-cost (B:C) ratio.Furthermore, the outcomes of the present study align with the results of previous research**Dwivedi*et al.* (2014),Patra *et al.* (2019),Verma *et al.* (2022)and Gupta *et al.* (2022)**

Conclusion

The study shown that the use of NPK, Zinc, Sulphur, FYM, Azotobacter, and PSB led to increased wheat grain yields, as well as higher net returns and B:C ratios; as a result, it will aid in improving the farmers' socioeconomic condition. For boosting the output and profitability of wheat, NPK, Zinc, Iron, Sulphur, FYM, Azotobacter, and PSB application require special consideration.

Table-3:Impact of various treatment combinations on wheat's productivity parameters

Treatments	Grain Yield (q ha^{-1})	Straw Yield (q ha^{-1})

	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
T_1	17.90	19.84	18.87	26.87	31.43	29.15
T_2	38.90	39.75	39.32	55.24	60.88	58.06
T_3	42.23	42.29	42.26	58.06	62.63	60.35
T_4	40.96	41.89	41.43	57.17	61.21	59.19
T_5	42.31	42.98	42.65	59.68	63.56	61.62
T_6	42.58	43.56	43.07	61.88	64.76	63.32
T_7	42.95	45.08	44.02	61.96	65.01	63.49
T_8	44.35	45.19	44.77	62.01	65.53	63.77
T_9	45.90	47.16	46.53	62.86	66.63	64.75
T_{10}	48.60	49.93	49.27	63.15	67.53	65.34
T_{11}	42.49	43.36	42.93	59.79	63.61	61.70
SE(m) ±	**0.31**	**0.34**	**0.39**	**0.27**	**0.23**	**0.39**
C.D. at 5 %	**0.93**	**1.00**	**1.24**	**0.80**	**0.68**	**1.22**

Table-4: Impact of various treatment combinations on wheat's productivity parameters

Treatments	Biological yield (q ha^{-1})			Harvest Index (%)		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
T_1	44.77	51.27	48.02	39.98	38.69	39.34
T_2	94.14	100.63	97.38	41.32	39.50	40.41
T_3	100.29	104.92	102.61	42.11	40.31	41.21
T_4	98.13	103.10	100.62	41.74	40.63	41.18
T_5	101.99	106.54	104.27	41.48	40.34	40.91
T_6	104.46	108.32	106.39	40.76	40.21	40.49
T_7	104.91	110.09	107.50	40.94	40.95	40.94
T_8	106.36	110.72	108.54	41.70	40.81	41.26
T_9	108.76	113.79	111.28	42.20	41.44	41.82
T_{10}	111.75	117.46	114.61	43.49	42.51	43.00
T_{11}	102.28	106.97	104.63	41.54	40.53	41.04
SE(m) ±	**0.58**	**0.57**	**0.64**	**0.08**	**0.12**	**0.23**
C.D. at 5 %	**1.73**	**1.67**	**2.02**	**NS**	**NS**	**NS**

Table-5:Economic analysis of wheat cultivation influenced by diverse treatment combinations

Treatment	Cost of cultivation (₹ / ha)			Gross return (₹ / ha)		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
T_1	30651	32028	31339.5	54162	65122	59642
T_2	37904	39281	38592.5	115495	125756	120626
T_3	45404	46718	46061.0	124046	135318	129682
T_4	38764	40141	39452.5	120915	133376	127146
T_5	48078	49455	48766.5	125338	137452	131395
T_6	42604	44263	43433.5	127271	139581	133426
T_7	39315	40724	40019.5	128198	142844	135521
T_8	44015	45706	44860.5	130998	143481	137240
T_9	45445	47201	46323.0	134654	148331	141493

T_{10}	53805	55661	54733.0	140190	154632	147411
T_{11}	39718	41095	40406.5	125771	138258	132015

Table-6: Economic analysis of wheat cultivation influenced by diverse treatment combinations

Treatments	**Net return (₹ / ha)**			**B:C ratio**		
	2021-22	**2022-23**	**Pooled**	**2021-22**	**2022-23**	**Pooled**
T_1	23511	31717	27614	0.76	0.94	0.85
T_2	77587	85098	81343	2.04	2.09	2.06
T_3	78642	87160	82901	1.73	1.80	1.76
T_4	82151	91858	87005	2.11	2.21	2.16
T_5	77260	86620	81940	1.60	1.61	1.58
T_6	84667	93659	89163	1.98	2.03	2.05
T_7	88883	100712	94798	2.26	2.39	2.32
T_8	86983	96085	91534	1.97	2.02	1.99
T_9	89209	99375	94292	1.96	2.04	2.0
T_{10}	86385	97316	91850	1.61	1.69	1.65
T_{11}	85954	95786	90870	2.16	2.25	2.20

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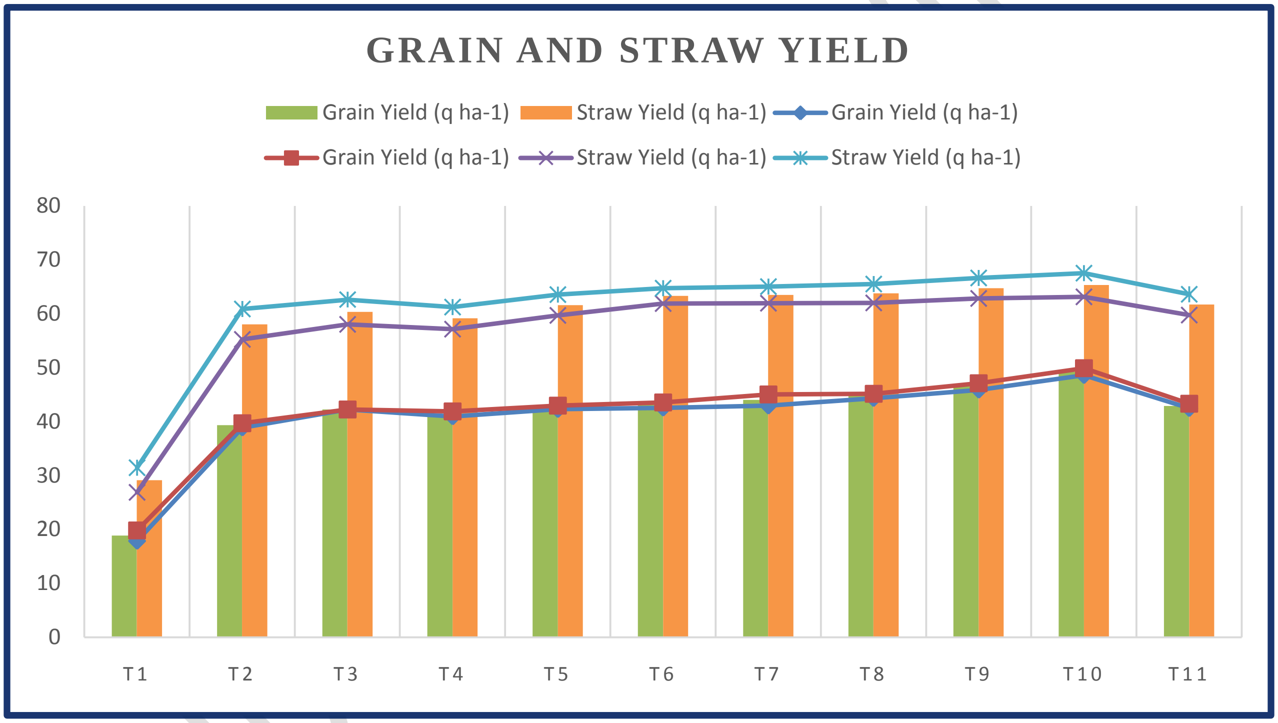

Fig.-1: Effect of different treatment combinations on grain and straw yield of wheat

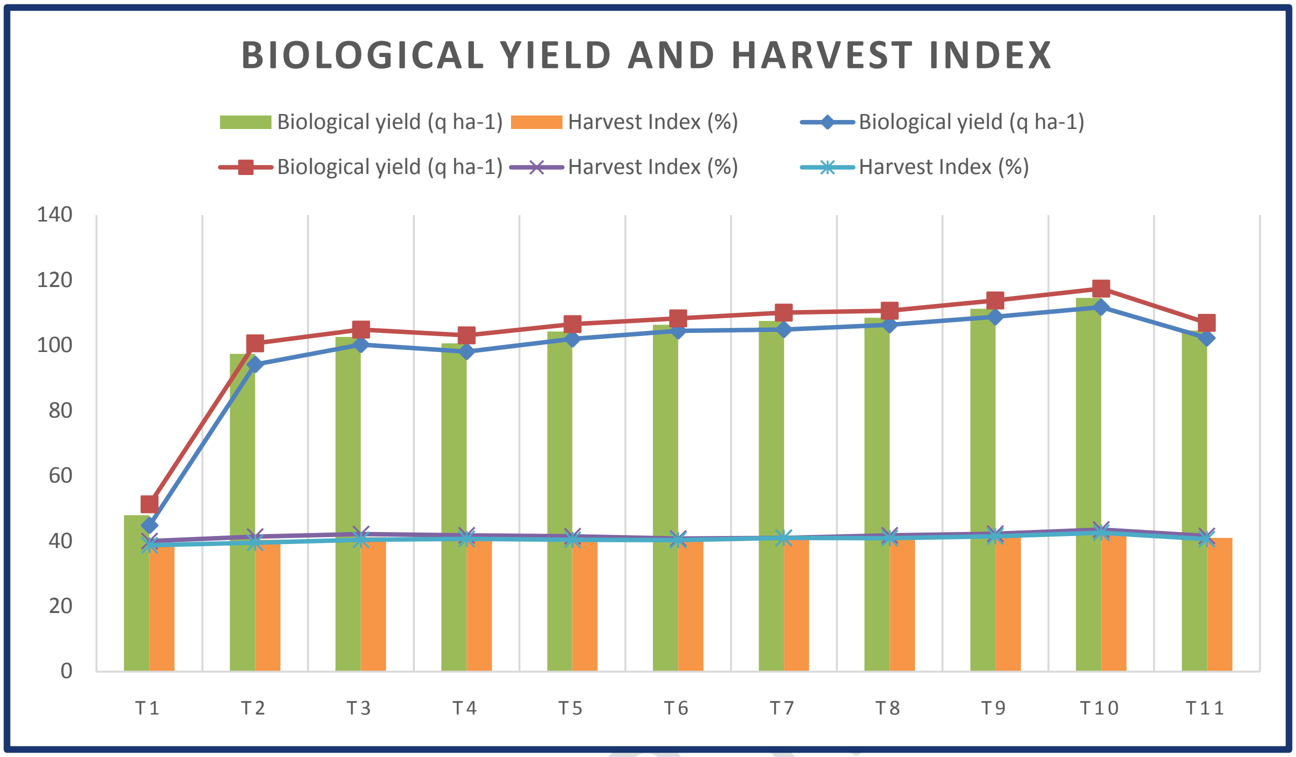

Fig.-2: Effect of different treatment combinations on biological yieldand harvest index of wheat