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IMPACT OF GREEN SOIL (*TRICHODERMA HARZIANUM*) ON WHEAT GRAIN YIELD IN PESHAWAR VALLEY

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Abstract

*The present study evaluated the effects of Trichoderma-enriched soil (green soil), inorganic fertilizer, and their combined application on the growth and grain yield of two wheat (*Triticum aestivum *L.) cultivars, Khyber-23 and Gulzar-19. The experiment was conducted at the Cereal Crops Research Institute using a split-plot arrangement in a randomized complete block design with three replications. Wheat cultivars were assigned to the main plots, whereas fertilizer treatments comprising control, inorganic fertilizer, green soil, and their combined application were allocated to the subplots. Fertilizer treatments significantly influenced most growth and yield traits, and significant cultivar × fertilizer interactions were observed for several parameters. The combined application of inorganic fertilizer and Trichoderma enriched soil produced superior performance compared with the control and individual fertilizer applications. Gulzar-19 recorded higher spike weight and grain weight per spike, whereas Khyber-23 achieved the highest 1000-grain weight and grain yield under the combined treatment. Overall, integrating biofertilizer with inorganic fertilizer enhanced wheat growth and productivity, indicating that this nutrient management strategy can improve crop performance while supporting sustainable wheat production.*

INTRODUCTION

Spring Wheat *(Triticum aestivum* L.*)* is the essential food of many developing countries. Nearly two billion people, representing about 36% of the world's population, depend on hexaploid wheat as their primary food source. It serves as a staple food for over a billion people and contributes nearly 20% of daily calorie and protein intake of humans (Shiferaw *et al*., 2013). Similarly, wheat (*Triticum aestivum* L.) is considered as one

of the grain crops with the maximum global yields and with the annual utilization of 791.2 million tons (Liu *et al*., 2024).

In Pakistan Wheat (*Triticum aestivum* L.) were sown on an area of 9.63 thousand hectares according to data from the Ministry of National Food Security and Research during 2023-24, producing a record 31.40 million tons with an average yield of 3331 kg ha^{-1}. In Khyber Pakhtunkhwa, the crop covered 0.78 million hectares and produced 1.6 million tons of grain (Ministry of Finance, 2023–24).

Biofertilizer is derived from two words i.e. life and fertilizer. The term bio fertilizer is used for a product that contain living or dormant microorganisms i.e. fungi, algae, bacteria and actinomycetes, alone or in combination, that help in nitrogen fixation from atmosphere or solubilizing important and producing growth promoting substance (Naveed *et al.,* 2015). Unlike chemical fertilizers, biofertilizers do not directly supply nutrients but enhance nutrient availability and plant growth. They can be categorized into four types: (1) nitrogen fixing microbes (*Azospirillum, Rhizobium, Acetobacter, Azolla, blue-green algae, Azotobacter*); (2) phosphate solubilizing organisms (*Aspergillus*, vesicular arbuscular mycorrhiza, *Bacillus, Pseudomonas*); (3) compost degrading cellulolytic and ligninolytic bacteria; and (4) plant growth promoting rhizobacteria, including *Azospirillum, Azotobacter, Pseudomonas,* and *Bacillus* with *Rhizobium*, which enhance crop growth and yield (Naveed *et al*., 2015).

Chemical fertilizers are widely employed to achieve high yield crops. However, the excessive use of fertilizers is rapidly harming the soil and environment. Similarly, around 156 million tons of commercial fertilizers are used annually worldwide (Anonymous, 2012). The high requirement of foreign cash or internal resources for fertilizer production shows the need for innovative, affordable, and environmentally friendly nutrient sources. Biofertilizers offer a cost effective, renewable option and can play a key role in integrated nutrient management.

The plant growth promoting *rhizobacteria* has dual role, act both as bioprotection agents and biofertilizers, making them essential for sustainable agriculture. Their use in leguminous and non-leguminous crops is common in industrialized countries and their adoption is steadily increasing in other regions.

Pakistan is an agriculture based country, highly dependent on farming for its economy (Naveed *et al*., 2015). Biofertilizer use remains very limited, contributing less than 2% of total fertilizer consumption (FAO, 2006). In 2024, Pakistan imported US$825.56 million worth of chemical fertilizers, highlighting the need to enhance biofertilizer adoption for sustainable and viable agriculture.

The use of crop beneficial microbes as biofertilizers and bioprotectants is becoming increasingly popular for enhancing crop production with low inputs and minimal ecological impact (Bulgari et al., 2015). Species of *Trichoderma* are widely used as biological control agents against plant pathogenic oomycetes, nematodes, and fungi (Monte and Hermosa, 2022). Moreover, *Trichoderma* produces various types of plant hormones such as abscisic acid (ABA), cytokinin's (CK), gibberellins (GA), indole-3-aceticacid (IAA) and salicylic acid (SA) which help in balancing the internal plant hormone network system that results in the signaling of plant immune system against biotic stresses (Illescas *et al.*, 2021). Furthermore, 1-aminocyclopropane-1-carboxylic acid (ACC) deaminase (ACCD) activity of *Trichoderma* spp. has the ability to change the ethylene (ET) concentration in the crops plant which results in promoting growth (Illescas *et al.,* 2022). Recent studies highlight the importance of biofertilizers in reducing chemical fertilizer use by 40–50%, supporting sustainable agriculture. Biofertilizer application can enhance plant growth and yield by up to 30% (Kadhum *et al*., 2021). Additionally, biofertilizer inoculation improves phosphorus availability, increases nutrient uptake, and stimulates root growth through microbial production of auxins (Sellamuthu *et al*., 2017).Therefore, the present study was conducted to evaluate the individual and combined effects of *Trichoderma harzianum*-enriched soil and inorganic fertilizer on the growth and grain yield of two wheat cultivars, Khyber-23 and Gulzar-19.

Materials and Methods

Experimental site and plant materials

The biofertilizer experiment was conducted at the Cereal Crops Research Institute to evaluate the impact of selected fertilizer treatments and green soil (*Trichoderma*-enriched soil) on the vegetative growth and grain yield of two wheat (*Triticum aestivum* L.) cultivars (Khyber-23 and Gulzar-19).

Experimental design and treatments

The experiment was conducted using a split-plot arrangement in a randomized complete block design (RCBD), with wheat cultivars as the main plot factor and fertilizer treatments as the sub-plot factor. The main plots was assigned to the two wheat varieties i.e. Khyber-23 and Gulzar-19, while each main plot was subdivided into four sub-plots representing the following fertilizer treatments: (1) Control, (2) chemical Fertilizer, (3) Green Soil , and (4) Green Soil + chemical Fertilizer. Each treatment combination was replicated three times, ensuring robust statistical analysis. The plots were five meters long and two meters wide, with 0.25 meters row spacing, and each plot were contain eight rows of wheat. Soil samples were taken before planting and after harvest to evaluate the effects of treatments on soil nutrients and microbial activity. The split-plot design allows for a detailed analysis of the main effects of wheat variety and fertilizer treatments, as well as their interaction, providing insights into how these factors influence wheat growth and productivity. The study aimed to optimize the use of fertilizers and green soil to enhance wheat yield and soil health, contributing valuable information for sustainable agricultural practices.

Following parameters were be examined

The following are parameters which were measured during the experiment.

Days to Heading

Days were counted from sowing until the flag leaf spikes appear.

Spike weight (g)

Each of the 10 randomly chosen spikes was used to measure each spikes weight using a sturdy, sensitive electronic balance.

Grains weight spike^{-1}

For every wheat genotype, the number of grains spike^{-1} was physically counted and measured.

Thousand Grain Weight (g)

Once the thousand grains have been physically count up, they were weighted using an electronic balance (Al-Myali, 2021).

Grain Yield (kg ha^{-1})

Grain yield (kg ha^{-1}) was measured using an electronic balance (Hadi, 2025).

Statistical Analysis

The approach recommended by Steel and Torrie (1980) were be used to analyze data variance. To separate treatments means, the Least Significant Difference (LSD) test will be employed. The ANOVA and trait correlation will be ascertained using Software Statics version 8.1.

Results and Discussion

Days to heading

Analysis of variance ANOVA showed highly significant ($P \leq 0.01$) among fertilizer treatments and varieties interaction for days to heading (Table. 2). Days to heading was varied in number however, it was statistically similar for wheat cultivars i.e. Gulzar-19 and Khyber-23 shown in (Figure-1) in main plot. However, Days to heading had significantly affected by fertilizer (inorganic and biofertilizer) and the interaction between the varieties and fertilizers was also significant. The LSD value for days to heading was 1.84 and coefficient of variation (CV) was 0.86 which showed the authenticity of the experiment. The minimum days to heading (111f) was noted for wheat variety Gulzar-19 in control. Maximum days to heading (130a) was noted for treatment combination such as Gulzar-19 (NP + green soil) shown in (Table.1). Moreover, it was statistically similar for wheat cultivar Khyber-23 (129ab) at NP and green soil interaction. Mohammad *et al.*, (2022) stated in 2019-20 and 2020-21 seasons that biofertilizer alone or in combination improved days of heading over the control treatment. Similarly to Talgre *et al.*, (2009) reported that split nitrogen application around the heading stage increases grain protein and gluten.



Fig: 1 Picture showing days to heading.

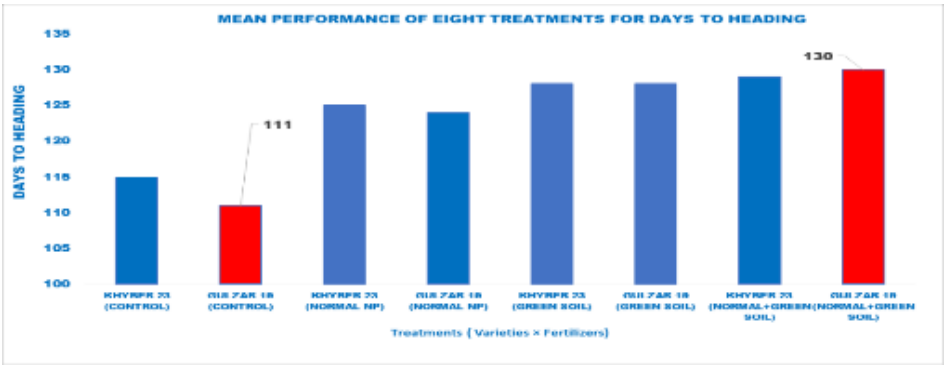


Fig: 1. Mean performance of eight treatments for days to heading in wheat cultivars Gulzar-19 and Khyber-23.

Spike weight

ANOVA indicated significant variation ($P \leq 0.05$) among fertilizer treatments and varieties interaction for spike weight (Table. 2). Spike weight was statistically different for wheat cultivars i.e. Gulzar-19 and Khyber-23 shown in (Figure-2) in main plot. However, Spike weight had significantly affected by fertilizer (inorganic and biofertilizer) and the interaction between the varieties and fertilizers was also significant. The LSD value for spike weight was 0.045 and coefficient of variation (CV) was 0.46 which showed the authenticity of the experiment. The minimum spike weight (3.77g) was noted for wheat variety Khyber-23 in control. Maximum

spike weight (5.10a) was noted for treatment combination such as Gulzar-19 (NP + green soil). Moreover, it was statistically not similar for wheat cultivar Khyber-23 and Gulzar-19 (4.70b) at NP and green soil interaction shown in (Table.1). Naji *et al.*, (2025) observed that biofertilizer indicated a positive effect on growth rate and increased the dry weight of the plant. Likewise, Vafa *et al.*, (2021) reported that the interaction between *Azotobacter sp.*, *Azospirillum sp.* and *Mycorrhiza* improved spike weight and nutrient absorption, ultimately increased grain yield of wheat.



Fig: 2. Picture showing spike weight.

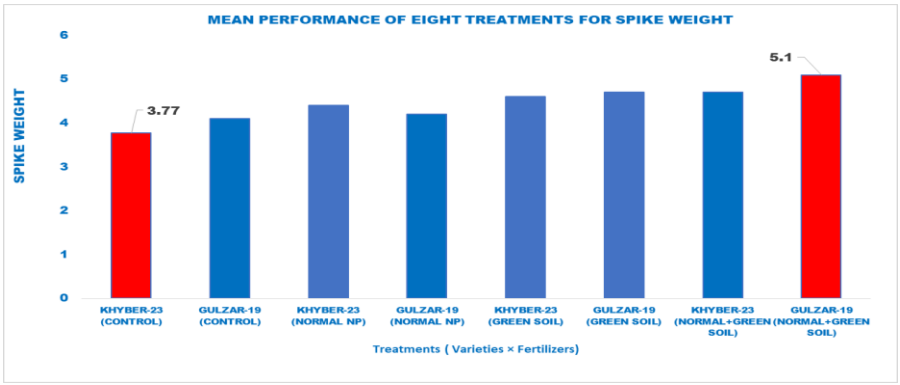


Fig: 2. Mean performance of eight treatments for spike weight in wheat cultivars Gulzar-19 and Khyber-23.

Grain Weight per spike

Fertilizer treatments and varieties × fertilizer interaction for grain weight per spike were significantly influenced ($P \leq 0.05$) (Table. 2). Grain weight per spike was statistically varied for wheat cultivars i.e. Gulzar-19 and Khyber-23 shown in (Figure-3) in main plot. However, Weight per spike Grain weight per spike had significantly affected by fertilizer (inorganic and biofertilizer) and the interaction between the varieties and fertilizers was also significant. The LSD value for grain weight per spike was 0.045 and coefficient of variation (CV) was 0.69 which showed the authenticity of the experiment. The minimum grain weight per spike (2.27g) was noted for wheat variety Khyber-23 in control. Maximum weight per spike (3.60a) was noted for treatment combination such as Gulzar-19 (NP + green soil). Moreover, it was statistically different for wheat cultivar Khyber-23 and Gulzar-19 (3.20b) at NP and green soil interaction shown in (Table.1). Mutlu *et al.*, (2021) reported that the treatment of *Trichoderma* in the experiment enhanced grain weight per spike comparad to the control. Likewise, Khattab *et al.*, (2016) noted that the combined application of N_2-fixing biofertilizer and chemical nitrogen fertilizer effectively increased grain weight per spike.

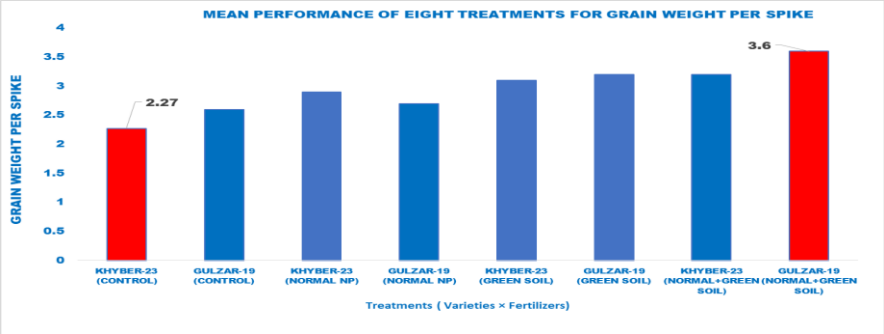


Fig: 3. Mean performance of eight treatments for grain weight per spike in wheat cultivars Gulzar-19 and Khyber-23.

1000 grain weight

ANOVA revealed highly significant variation ($P \leq 0.05$) due to fertilizer treatments and the interaction between varieties and fertilizer treatments (Table. 2). Thousand grain weight was varied in quantity however, it was statistically similar for wheat cultivars i.e. Gulzar-19 and Khyber-23 shown in (Figure-4) in main plot. However, Thousand grain weight had significantly affected by fertilizer (inorganic and biofertilizer) and the interaction between the varieties and fertilizers was also significant. The LSD value for thousand grain weight was 4.13 and coefficient of variation (CV) was 2.15 which showed the validity of the experiment. The minimum thousand grain weight (33.23d) was noted for wheat variety Khyber-23 in control. Maximum thousand grain weight (53.33a) was noted for treatment combination such as Khyber-23 (NP + green soil). Moreover, it was statistically similar for wheat cultivar Gulzar-19 (47.07b) at NP and green soil interaction shown in (Table.1). Abdallah *et al.*, (2013) reported that biofertilizer improved the natural nutrient activities in the soil and significantly improved thousand grains weight of wheat. Likewise, Gomaa (2024) reported that the use of nitrogen and phosphorus biofertilizer alone or together effectively increase 1000-grain weight.



Fig: 3. Picture showing 1000 grain weight.

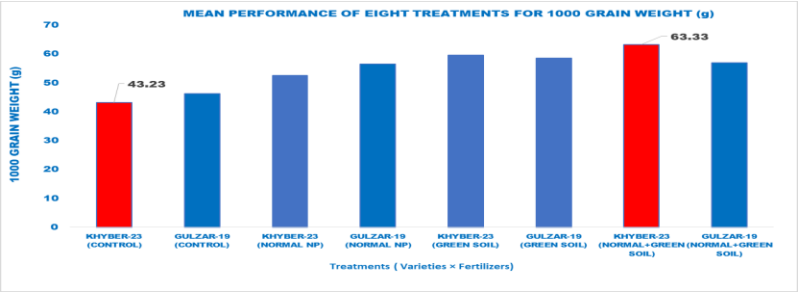


Fig: 4. Mean performance of eight treatments for 1000 grain weight in wheat cultivars Gulzar-19 and Khyber-23.

Grain yield

ANOVA result demonstrated significant variation ($P \leq 0.05$) among fertilizer treatments and varieties interaction for grain yield (Table. 2). Grain yield was statistically different for wheat cultivars i.e. Gulzar-19 and Khyber-23 shown in (Figure-5) in main plot. However, Grain yield had significantly affected by fertilizer (inorganic and biofertilizer) and the interaction between the varieties and fertilizers was also significant. The LSD value for grain yield was 86.99 and coefficient of variation (CV) was 0.78 which showed the authenticity of the experiment. The minimum grain yield (4533f) was noted for wheat variety Khyber-23 in control. Maximum grain yield (7545a) was noted for treatment combination such as Khyber-23 (NP + green soil). Moreover, it was statistically varied for wheat cultivar Gulzar-19 (7263b) at NP and green soil interaction shown in (Table.1). Hospodarenko, (2022) who observed that nitrogen fertilizers was essential for winter wheat cultivation, as their application leads to higher grain yields compared to unfertilized treatments. Likewise, Alobaidy *et al.*, (2021) reported that mycorrhizal fungi enhancing macronutrient uptake, which improved growth, grain production.

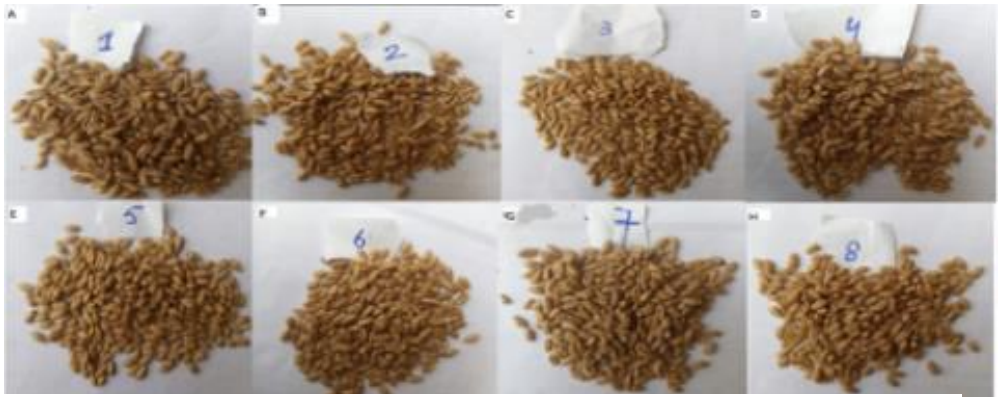


Fig: 4. Picture showing grain yield.

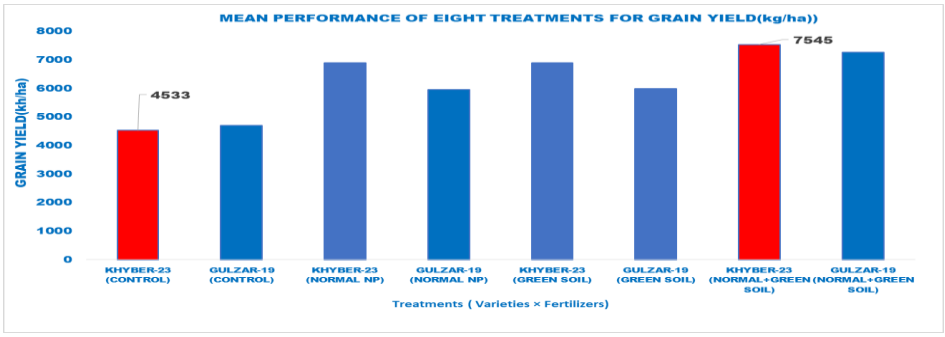


Fig: 5. Mean performance of eight treatments for grain yield (kg/ha) in wheat cultivars Gulzar-19 and Khyber-23.

Table 1. Mean performance of days to heading, spike weight, grain weight per spike, 1000 grain weight (g), grain yield (kg/ha) as affected by biofertilizer.

TREATMENT	Days to heading	Spike weight	Grain weight per spike	1000 grain weight (g)	Grain yield (kg/ha)
KHYBER-23 (CONTROL)	115 e	3.77 g	2.27 g	33.23 d	4533 f
GULZAR-19 (CONTROL)	111 f	4.10 f	2.60 f	36.33 d	4714 e
KHYBER-23 (NORMAL NP)	125 d	4.40 d	2.90 d	42.67 c	6895 c
GULZAR-19 (NORMAL NP)	124 d	4.20 e	2.70 e	46.50 bc	5956 d
KHYBER-23 (GREEN SOIL)	128 c	4.60 c	3.10 c	49.67 b	6895 c
GULZAR-19 (GREEN SOIL)	128 bc	4.70 b	3.20 b	48.67 b	6004 d
KHYBER-23 (NORMAL+GREEN SOIL)	129 ab	4.70 b	3.20 b	53.33 a	7545 a
GULZAR-19 (NORMAL+GREEN SOIL)	130 a	5.10 a	3.60 a	47.07 b	7263 b
LSD	1.8442	0.0452	0.0452	4.1389	86.996

Table 2. Analysis of variance for wheat cultivars Gulzar-19 and Khyber-23 under inorganic and biofertilizer treatments on days to heading, spike weight, grain weight per spike, 1000 grain weight (cm), grain yield (kg/ha).

Source	DF	Days to heading	Spike weight	Grain weight per spike	1000 grain weight (g)	Grain yield (kg/ha)
Rep	2	0.542	0.00042	0.00042	0.645	1284
Varieties	1	2.667^{NS}	0.15042*	0.15042*	0.042^{NS}	1397803*
Error (a)	2	0.292	0.00042	0.00042	5.043	840
Fertilizer	3	333.167**	1.06375**	1.06375**	297.108**	8089800**
Variety× Fertilizer	3	5.444*	0.11042**	0.11042**	32.274**	427745**
Error (b)	12	1.139	0.00042	0.00042	1.383	2334
CV (%)	--	0.86	0.46	0.69	2.15	0.78

* =Significant at 0.05 level of probability, ** = Highly significant at 0.01 level of probability, NS = Non-significant at 0.6 level.

Conclusion

The combined application of inorganic fertilizer and *Trichoderma harzianum*-enriched soil significantly improved the growth and yield performance of both wheat cultivars. Gulzar-19 produced higher spike weight and grain weight per spike, whereas Khyber-23 achieved the highest 1000-grain weight and grain yield under the combined fertilizer treatment. Overall, the combined application of inorganic fertilizer and *Trichoderma*-enriched soil was more effective than either treatment applied alone. These findings indicate that integrating biofertilizer with inorganic fertilizer has the potential to improve wheat productivity and represents a promising approach for sustainable nutrient management.

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