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RESPONSE OF DIFFERENT RICE CULTIVARS TO GREEN SOIL (*TRICHODERMA HARZIANUM* L.) AND NPK (NITROGEN, PHOSPHORUS, POTASSIUM) LEVELS

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Abstract
Rice production is influenced by genotype, soil health, management factors and optimal nutrient supply. Farmers face declined yields due to lack of awareness about high yielding cultivars, deteriorating soil fertility and imbalanced nutrition management. Farmers may boost rice production per unit area by using superior rice cultivars, improving soil health and balanced fertilizer management. Keeping in view the aforementioned facts, a field study was carried out in order to determine the response of green soil (Trichoderma harzianum L.) in addition to NPK levels to coarse rice (KSK-133) and fine rice (Pk-386) at the Agricultural Research Institute (ARI), Dera Ismail Khan, Khyber Pakhtunkhwa (KPK), Pakistan during cropping season 2022. The layout method in this experiment was tri-replicate randomized complete block design (RCBD) with split plot arrangements. The treatments included control (having no fertilizer), NPK (RFD), green soil (1.75 kg ha-1), green soil + 75% NPK (RFD), green soil + 50% NPK (RFD) and green soil + 25% (RFD). The results revealed that growth parameters such as leaf area index, crop growth rate and number of tillers (m-2) as well as yield attributes were found significantly better for coarse variety (KSK-133). However, number of spikelets was recorded maximum for fine variety (PK-386). Among the treatments, recommended doses of NPK resulted in maximum growth and yield including leaf area index, number of tillers m-2 and paddy yield with minimum sterility (%). The results showed that coarse variety (KSK-133) with application of NPK (RFD) proved to be the best under agro-climatic conditions of Dera Ismail Khan.
Keywords: *Coarse rice, Fine rice, NPK levels, Productivity, Trichoderma harzianum L.*

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most essential cereal crops in world. Rice is cultivated on around 9% area of the planet and provides 21% per capita energy and 15% per capita protein as well as feeding 2.5 billion people globally (1). Almost 90% of the world's rice is produced by Asian countries with China, India and Indonesia leading the way (2). In terms of global rice production in 2023, China was at the top with 7.11 tonnes per hectare, followed by India with 4.21 tonnes per hectare (3). In Pakistan, despite the availability of high yielding cultivars farming community lacks use of inappropriate production technology and soil nutrient management (4).

Coarse rice varieties are typically high-yielding and resilient, rendering them appropriate for extensive cultivation and fulfilling staple food requirements. Conversely, fine rice varieties are esteemed for their exceptional grain quality, aroma, and market demand, frequently fetching higher prices. This research seeks to analyze both cultivars to offer insights into enhancing yield and quality under diverse cultivation conditions and market demands, thereby ensuring a holistic strategy for advancing rice production systems.

Nitrogen plays an important function in growth and development of crops. All key functions in plants are performed by using protein, of which nitrogen is an essential element including chlorophyll and enzymes; and nitrogen aids plants in synthesis and use of carbohydrates (5). Phosphorus, the second important nutrient after nitrogen is vital for root proliferation, consistent grain filling and improved grain yield and quality, as well as being a component of nucleotides like ADP and ATP energy bonds, and being engaged in a variety of processes like photosynthesis, mitotic activity, tissue growth, and development (6). Potassium is required for preservation of electrical potential across cellular membranes as well as cellular turgor, which promotes cell expansion and enlargement, stomata opening and closing, and pollen tube production. It is also involved in the activation of multiple enzymes and nitrate translocation (7).

Micro-organisms are an important, but unseen component of agricultural systems. Many free-living bacteria create beneficial biological relationship with agricultural plants by living in rhizosphere around roots and colonizing their roots, a process not limited to leguminous crops (8). *Trichoderma spp.* (a fungus species), provides significant advantages in farming systems by mitigating biotic and abiotic pressures (9). It administers the rate of plant growth and suppresses proliferation of plant pathogenic bacteria. Root rot, damping off, wilt, fruit rot and other common plant diseases are all prevented by *Trichoderma spp*. (10). *Trichoderma spp.* has been shown to have several mechanisms for increasing rice physiological processes such as plant height, tiller number, root length and root fresh weight, net photosynthetic rate, transpiration, water use efficiency and internal CO_2 concentration (11). Its ability to accelerate development, nutrients absorbance and change in rhizosphere is linked to its success in soil ecosystem, as well as its role as a natural decomposer (12). Thus, using *Trichoderma*-enriched biofertilizer effectively, either alone or in conjunction with chemical fertilizer, may increase crop output and quality while reducing burden of NPK and associated environmental impact (13).

Cost of NPK fertilizers is increasing day by day. Due to which, it is very difficult for farmers to provide complete fertilizer to the crop. The effect of *Trichoderma harzianum* L., alone or blended with other combinations have been to be proved effective on different crops. The experiment was performed to conclude the response of *Trichoderma harzianum* L., in enhancing the growth and yield attributes of rice.

Pakistan's land and water resources are progressively depleting, whereas its population is expanding rapidly. Due to which, rice production is far insufficient to meet the country's growing population. The average annual per acre production of rice in our country is very low as compared to developed countries. As a result, enhanced production technologies and better management of agricultural inputs are necessary to increase rice output and quality. Precise uses of fertilizers along with specific knowledge about cultivars are the most important variables that contribute to improved yield and quality (14). Best fertilizer application rate is one that yields highest economic returns at lowest expense (15). As the price of inorganic fertilizers (NPK) continues to rise, organic fertilizer (*Trichoderma harzianum* L.) seems to be the most cost-effective option for farmers. Keeping in view the above problems, the current research was carried out to observe the response of different rice cultivars to green soil and NPK levels. This research aims at finding the best alternative against costly fertilizers (NPK) which were inexpensive and easily available in the market.

The objectives of the study were: to assess the effects of *Trichoderma harzianum* L., fungi in addition to different NPK levels on rice cultivars, to study the impact of various NPK rates (25%, 50%, 75% and 100% RFD) on rice growth and yield and assessing the economic feasibility of using *Trichoderma harzianum* L. as a substitute for NPK

MATERIALS AND METHODS

The field experiment was carried out at ARI (Agricultural Research Institute), Dera Ismail Khan during 2022 cropping season. The research area was located at 139.11 meter above sea level. The latitude and longitude of research area was 31.87042955° and 70.88425593°.

The trial was conducted by using RCBD (Randomized Complete Block Design) with three replications along with split plot arrangement. Main plot consisted of varieties (KSK-133 and PK-386) while treatments were arranged in sub-plots. Treatments included *Trichoderma harzianum* L., with different NPK levels (100%, 75%, 50% and 25% of RFD). A net plot size of 2.25 m^2 (1.5 m × 1.5 m) was maintained for each treatment. Row to row and plant to plant spacing were maintained at 20 cm & 15 cm, respectively. Two fresh seedlings were transplanted per hill at a depth of 4 cm. Urea, DAP and SOP were used to supply nitrogen, phosphorus and potassium, respectively while *Trichoderma harzianum* L., made available from Agro Services was applied in the form of Green Soil (Trade name). Recommended dose for coarse and fine rice was 140:60:60 kg ha^{-1} NPK and 120:60:60 kg ha^{-1} NPK, respectively. Different doses of NPK were applied to selected plots after 10 days of *Trichoderma harzianum* L., application. Phosphorus and potassium were applied at seedbed preparation, while nitrogen was applied at three split doses. The 1st dose of nitrogen (50%) was applied at seedbed preparation, 2nd (25%) at tillering and 3rd (25%) at panicle emergence stage. The recommended dose of Zinc @ 12 kg ha^{-1} was applied after 24 days of transplantation to all plots. Foliar application of weedicide was applied 25 days after transplantation. Weedicide Vinsta was applied to control weeds and Furadon granules were applied to control grasshopper and borers. All agronomic practices required for rice cultivation were adopted uniformly.

Treatments kept were; V_1: Coarse Rice (KSK-133), V_2: Fine rice (PK-386). T_1: Control (having no fertilizers), T_2: NPK RFD, T_3: Green soil (1.75 kg ha^{-1}), T_4: Green soil + 25 % NPK, T_5: Green soil + 50 % NPK, T_6: Green soil + 75 % NPK. The data obtained for each parameter was statistically analyzed using computer software "STATISTIX-8.1" for generation of ANOVA (16). Means were separated using Least Significant difference test at 5% level of probability.

RESULTS AND DISCUSSION

LEAF AREA INDEX (30 DAYS AFTER TRANSPLANTATION)

The total area of leaves per unit ground area is represented by LAI, which is directly proportional to the quantity of light that is intercepted by plants. Recorded data for leaf area index (30 days after transplantation) are shown in Table I. The analysis of variance revealed non-significant difference between varieties. However, the coarse variety (KSK-133) had the greater leaf area index of 5.36, compared to the fine variety (PK-386), which had a leaf area index of 2.80.

Table I. Mean values for leaf area index (30 and 50 days after transplantation), crop growth rate (g m^{-2} day^{-1}) and net assimilation rate (g m^{-2} day^{-1}) and number of tillers (m^{-2}) as affected by rice cultivars and green soil (*Trichoderma harzianum* L.) and NPK levels

Treatments	Leaf area index (30 days after transplantation)	Leaf area index (50 days after transplantation)	Crop Growth Rate (g m^{-2} day^{-1})	Net Assimilation Rate (g m^{-2} day^{-1})	Number of tillers (m^{-2})
			Varieties		
V_1	5.36 ^{NS}	5.88 a	18.72 a	3.28 ^{NS}	395 a
V_2	2.80	3.39 b	11.89 b	3.76	252 b
$LSD_{0.05}$	3.18	1.42	1.34	1.54	25.00
			***Trichoderma harzianum* L., with NPK levels**		
T_1	3.30 c	3.68 c	14.44 c	3.21 bc *	295.33 c
T_2	4.90 a	5.68 a	14.83 bc	2.90 c	340.17 a
T_3	3.51 bc	3.95 c	14.25 c	4.21 a	316.00 b
T_4	4.40 a	4.94 b	17.03 a	3.71 ab	326.00 ab
T_5	4.14 ab	4.94 b	15.51 b	3.37 bc	331.00 a
T_6	4.22 ab	4.65 b	15.78 b	3.70 ab	332.50 a
$LSD_{0.05}$	0.76	0.59	1.04	0.58	14.98
			Varieties × *Trichoderma harzianum* L. with NPK levels		
V_1 T_1	4.41 ^{NS}	4.67 ^{NS}	15.96 c	2.72 b	356.33 d *
V_1 T_2	6.25	6.85	17.50 b	2.71 b	405.00 abc
V_1 T_3	4.89	5.11	16.30 bc	3.39 b	386.67 c
V_1 T_4	5.38	6.33	20.64 a	3.53 ab	394.00 bc
V_1 T_5	5.34	6.28	21.14 a	3.70 ab	409.00 ab
V_1 T_6	5.89	6.07	20.78 a	3.62 ab	419.00 a
V_2 T_1	2.20	2.70	12.91 d	3.70 ab	234.33 g
V_2 T_2	3.55	4.51	12.16 de	3.09 b	275.33 e
V_2 T_3	2.13	2.78	12.20 de	5.04 a	245.33 fg
V_2 T_4	3.43	3.54	13.41 d	3.90 ab	258.00 ef
V_2 T_5	2.95	3.60	9.88 f	3.04 b	253.00 fg
V_2 T_6	2.55	3.23	10.78 ef	3.78 ab	246.00 fg
$LSD_{0.05}$	3.21	1.52	1.80	1.62	29.67

The analysis of variance further indicated that the treatments differed significantly in respect to LAI. It was found that plots which received NPK (recommended dose) ranked 1st in performance and had maximum leaf area index of 4.90. However, plots that received green soil + 75% NPK performed better as well and are statistically similar with NPK (recommended dose) having leaf area index of 4.40. Plots which didn't receive any fertilizer (control) had minimum leaf area index of 3.30. Plots which received recommended dose of green soil had leaf area index of 3.51 and are statistically at par with control (no fertilizer). LAI of 4.22 and 4.14 were recorded from the plots treated with green soil + 25% NPK and green soil + 50% NPK, respectively. This might be linked to proper nutrient availability due to NPK levels, as well as adequate moisture conditions sustained throughout the crop growth season, which could have boosted soil nutrient providing capability. When fertilizer levels rise, leaf area index also rises (17, 18).

Analysis of variance showed non-significant results for interaction between varieties and treatments. However, coarse variety (KSK-133) had maximum leaf area index (6.25) when recommended dose of NPK was applied to the selected plots while minimum leaf area index (2.55) was recorded for fine variety (PK-386) when plots didn't receive any fertilizer (control).

LEAF AREA INDEX (50 DAYS AFTER TRANSPLANTATION)

Table I shows the results obtained for the leaf area index calculated 50 days after transplantation. The analysis of variance indicated that differences between the varieties were found statistically significant. In comparison to the fine variety (PK-386), which had a leaf area index of 3.39, the coarse variety (KSK-133) had higher leaf area index of 5.88. It might be attributable to the genetic composition of fine and coarse rice cultivars. Varieties different genetic makeup has a greatest effect on leaf area index (19).

The analysis of variance further revealed that LAI was found significantly different for different treatments. It was observed that plots that received NPK (recommended dose) performed best and had the highest leaf area index of 5.68. Green soil + 75% NPK, green soil + 50% NPK, and green soil + 25% NPK had leaf area indexes of 4.94, 4.94, and 4.65, respectively, and were found statistically equivalent. The smallest leaf area index of 3.68 was found in plots that did not receive any fertilizer (control). Despite the fact that plots that got the recommended dose of green soil had a leaf area index of 3.95 and were statistically similar to control plots. This may be related to NPK's (recommended level) beneficial effects on leaf growth, tillering, and photosynthetic activity. As amount of nutrients increases up to optimum level, leaf area index also increases reported by (18, 20). The effect of inorganic fertilizer on leaf area index is higher as compared to organic fertilizer (21). It is observed that different levels of fertility had a greatest effect on leaf area index of rice.

The interaction between varieties and treatments was found to be non-significant statistically according to analysis of variance. However, when recommended doses of NPK were given to selected plots, coarse variety (KSK-133) resulted in highest leaf area index (6.85), while fine variety (PK-386) produced lowest leaf area index (2.70) in control treatments (no fertilizer experimental plots). Table1 showed that no statistically significant difference was found between interaction of varieties and treatments after 30 and 50 days of transplantation.

CROP GROWTH RATE (G M^{-2} DAY^{-1})

Crop growth rate is the increase in total dry weight per unit land area of a crop in per unit time. Data collected for crop growth rate are presented in Table I. The differences between the varieties were determined to be statistically significant. Maximum crop growth rate was obtained by coarse variety (KSK-133) having 18.72 g m^{-2} day^{-1} as compared with fine variety (PK-386) whose crop growth rate was 11.89 g m^{-2} day^{-1}. This variation may be due to different genetic makeup of varieties. It is believed that since coarse variety had higher LAI throughout the season that may have resulted in higher CGR. Coarse variety had higher number of tillers, vigorous growth as well as higher dry matter accumulation. That's why, coarse variety had higher crop growth rate.

According to statistical analysis, the differences among the treatments were found to be significant as well for CGR. It was observed that maximum crop growth rate (17.03 g m^{-2} day^{-1}) was obtained by plots that received green soil + 75% NPK while minimum crop growth rate (14.25 g m^{-2} day^{-1}) was recorded when plots received recommended dose of green soil and this minimum crop growth rate was statistically similar to 14.44 g m^{-2} day^{-1} in plots didn't receive any fertilizer (control). Green soil + 25% NPK and green soil + 50% NPK were found statistically similar with each other and at par with recommended dose of NPK having crop growth rate of 15.78, 15.51 and 14.83 g m^{-2} day^{-1}, respectively. This might be due to microbial activities in the rhizosphere and better nutrients uptake by application of *Trichoderma harzianum* L., blended with inorganic fertilizer.

Statistical analysis indicated significant differences for interaction between two factors. Significantly higher crop growth rate was recorded for coarse variety (KSK-133) when it received green soil + 50% NPK having 21.14 g m^{-2} day^{-1} followed by 20.78 and 20.64 g m^{-2} day^{-1} recorded for same variety with green soil + 25% NPK and green soil + 75% NPK, respectively. Applying NPK (recommended dose) to KSK-133 resulted in crop growth rate of 17.50 g m^{-2} day^{-1} followed by green soil (recommended dose) whose crop growth rate was recorded to be 16.30 g m^{-2} day^{-1}. Minimum crop growth rate was recorded for fine variety (PK-386) having 9.88 g m^{-2} day^{-1} when it received green soil + 50% NPK. Based on the findings, it is noted that varied levels of fertilizer treatments influenced rice genotypes (22).

NET ASSIMILATION RATE (G M^{-2} DAY^{-1})

The net assimilation rate is the average rate of growth in total dry weight per unit leaf area, and it indicates the difference between the rate of photosynthesis in the leaves and the rate of respiration in the entire plant, both expressed in per unit leaf area. Table I shows the data recorded for net assimilation rate. It was found out from the analysis of variance that differences between the two varieties were observed to be non-significant. However, fine variety (PK-386) had more net assimilation rate of 3.76 g m^{-2} day^{-1} as compared to coarse variety (KSK-133) having net assimilation rate of 3.28 g m^{-2} day^{-1}.

Analysis of variance showed significant results for differences among treatments. Maximum net assimilation rate (4.21 g m^{-2} day^{-1}) was obtained when experimental plots received recommended dose of green soil only which was statistically at par with green soil + 75% NPK and green soil + 25% NPK having 3.71 and 3.70 g m^{-2} day^{-1} net assimilation rate, respectively. This might be due to production of secondary metabolites produced by *Trichoderma harzianum* L. as well as the additional effect of NPK on crop growth. Net assimilation rate of 3.37 g m^{-2} day^{-1} was recorded when green soil + 50% NPK applied to the plots which was statistically similar to control (no fertilizer) having 3.21 g m^{-2} day^{-1} net assimilation rate. Minimum net assimilation rate (2.90 g m^{-2} day^{-1}) was recorded when recommended dose of NPK were applied to the experimental plots. This might be due to environmental circumstances.

Differences between varieties and treatments were found to be significant according to analysis of variance. Maximum net assimilation rate of 5.04 g m^{-2} day^{-1} was obtained for fine variety (PK-386) when recommended dose of green soil was applied to the experimental plots which might be due to production of plant growth promoting metabolites and *Trichoderma* species beneficial effects on crop growth rate. Minimum net assimilation rate of 2.71 g m^{-2} day^{-1} was obtained from coarse variety when recommended dose of NPK was given to the experimental plots which were statistically similar with control plots having 2.72 g m^{-2} day^{-1} net assimilation rate which might be due to environmental factors. NPK (recommended dose) in both varieties didn't produce significant effect in response to net assimilation rate.

NUMBER OF TILLERS (M^{-2})

Data recorded for number of tillers (m^{-2}) are presented in Table I. Differences between the two varieties were found statistically significant. It was observed that coarse variety i.e., KSK-133 produced higher number of tillers m^{-2} (395) as compared to 252 tillers recorded for fine variety i.e., PK-386. This might be due to coarse variety's greater tendency for producing more tillers in the early growing season, as well as varietal variation in tiller counts (23-25).

Differences among the treatments were found statistically significant. Data presented in Table I revealed that the highest number of tillers (340.17) were produced by plots received NPK at recommended dose. Applying the optimum amount of NPK to rice would help to increase the number of tillers (26-28).

However, these tillers were statistically similar to 332.50 and 331.00 produced by the green soil + 25% NPK and green soil + 50% NPK, respectively. The lowest tillers were recorded in control plots (no-fertilizer) having 295.33 tillers m^{-2}. Applying green soil plus 75% NPK resulted in 326.00 tillers followed by 316.00 tillers recorded in plots received green soil @ 1.75 kg ha^{-1}.

Interaction between the two factors was also found significant. Significantly highest number of tillers were recorded for coarse variety (KSK-133) when it received green soil + 25% NPK having 419.00 tillers m^{-2} followed by 409.00 tillers and 405.00 tillers recorded for same variety with green soil + 50% NPK and recommended dose of NPK, respectively. Minimum tillers (234.33) were noted for fine variety (PK-386) having no fertilizer. Green soil along with 75% of NPK was found better as well when applied to coarse variety showing 394.00 tillers m^{-2}. This might be due to *Trichoderma* species beneficial effects as it produces secondary metabolites that play a novel role in enhancing growth of rice.

NUMBER OF SPIKELETS (PANICLE^{-1})

Data regarding number of spikelets panicle^{-1} are shown in Table II. Analysis of variance revealed that the differences between the varieties were found statistically significant. Fine variety (PK-386) resulted in significantly higher number of spikelets panicle^{-1} (13.13) in comparison with coarse variety (KSK-133) which produced 11.47 spikelets panicle^{-1}. This may be due to the genotype's different genetic composition and capability for nutrient absorption (29).

Table II. Mean values for number of spikelets (panicle-1) and Sterility (%), 1000-seed weight (g) and paddy yield (t ha-1) as affected by rice cultivars and green soil (Trichoderma harzianum L.) and NPK levels

Treatments	Number of spikelets (panicle^{-1})	Sterility (%)	1000-seed weight (g)	Paddy yield (t ha^{-1})
		Varieties		
V_1	11.47 b	9.37 b	29.23 a	5.56 a
V_2	13.13 a	10.31 a	26.13 b	3.99 b
$LSD_{0.05}$	1.16	0.47	2.67	0.29
		***Trichoderma harzianum* L., with NPK levels**		
T_1	11.60 NS	9.95 b *	27.68 NS	4.63 bc *
T_2	12.67	8.90 b	26.91	5.32 a
T_3	12.80	9.16 b	29.53	4.98 ab
T_4	12.80	11.47 a	27.63	4.50 c
T_5	12.53	9.93 b	27.96	5.30 a
T_6	11.43	9.65 b	26.38	3.92 d
$LSD_{0.05}$	1.56	1.36	2.08	0.47
		Varieties × *Trichoderma harzianum* L. with NPK levels		
$V_1 T_1$	10.13 NS	8.57 fghi	29.13 NS	5.00 de *
$V_1 T_2$	11.47	7.33 i	28.70	6.74 a
$V_1 T_3$	12.53	9.80 bcdef	31.20	5.29 cd
$V_1 T_4$	12.27	11.93 a	29.57	5.81 bc
$V_1 T_5$	11.60	8.87 efghi	29.30	5.96 b
$V_1 T_6$	10.87	9.7 bcdefg	27.50	4.53 efg
$V_2 T_1$	13.07	11.33 ab	26.23	4.26 fg
$V_2 T_2$	13.86	10.47 abcde	25.13	3.89 gh
$V_2 T_3$	13.07	8.53 fghi	27.87	4.67 def
$V_2 T_4$	13.33	11.00 abcd	25.70	3.18 i
$V_2 T_5$	13.47	11.00 abcd	26.63	4.63 ef
$V_2 T_6$	12.00	9.57 bcdefgh	25.26	3.30 hi
$LSD_{0.05}$	2.26	1.81	3.58	0.65

According to statistical analysis, the differences among the treatments were found to be non-significant. It was revealed in the recorded data that maximum number of spikelets panicle^{-1} (12.80) were recorded in plots received green soil @ 1.75 kg ha^{-1} and green soil + 75% NPK whereas, minimum spikelets (11.43) were recorded when plots received green soil + 25% NPK. The number of spikelets in rice increased as fertility levels increased (30) but, in our findings, number of spikelets was not influenced by increasing fertility levels. It might be due to environmental factors.

Statistical analysis indicated non-significant differences for interaction between varieties and treatments. Maximum number of spikelets were obtained from fine variety (PK-386) having 13.86 spikelets when experimental plots received recommended dose of NPK while minimum number of spikelets were obtained from coarse variety (KSK-133) having 10.13 spikelets when plots didn't receive any fertilizer (control).

STERILITY (%)

Data recorded for sterility (%) are shown in Table II. Statistical analysis showed significant differences between varieties. According to statistical analysis, PK-386 (fine variety) revealed higher sterility of 10.31% whereas; KSK-133 (coarse variety) showed minimum sterility of 9.37%. Differences in rice spikelet sterility across different cultivars were also found by some researchers (31, 32).

The differences among the treatments were found to be statistically significant. The maximum sterility (11.47%) was found when experimental plots were treated with green soil + 75% NPK. Minimum Sterility of 8.90% was noticed when plots received recommended dose of NPK. This was found statistically similar to 9.16, 9.65, 9.93 and 9.95% in plots received recommended dose of green soil, green soil + 25% NPK, green soil + 50% NPK and control plots (having no fertilizer), respectively. When fertility levels increased, spikelets sterility decreased (33, 34). However, it was proved from the experimental research that *Trichoderma harzianum* L. and different fertility levels of NPK are beneficial in decreasing the sterility of spikelets.

The interaction between varieties and treatments revealed significant results. The coarse variety (KSK-133) had the highest sterility of 11.93% when plots receive green soil + 75% NPK. Minimum sterility of spikelets (7.33%) was obtained from coarse variety (KSK-133) when plots received recommended dose of NPK. This might be attributable to the different genetic makeup of the varieties as well as enhanced photosynthetic activities due to application of NPK.

1000-SEED WEIGHT (G)

Table II shows the data collected for 1000-seed weight. Differences between varieties for 1000-seed weight were found to be statistically significant. KSK-133 (coarse variety) had the higher 1000-seed weight of 29.23 g, while PK-386 (fine variety) had the 1000-seed weight of 26.13 g. It seems that this is due to the cultivar's capacity to divide dry matter into seeds. Variation in 1000 grain weight might be attributed to differences in grain size, which is influenced by the genetic composition (35, 36).

The differences among the treatments were determined to be non-significant. Maximum 1000-seed weight of 29.53 g was obtained with the application of green soil (recommended dose). *Trichoderma* species enhance plant growth and yield which could be due to its ability to thrive in the root rhizosphere and the enhanced effectiveness of applied nutrients, as well as it promotes plant growth (37). *Trichoderma* species caused grain weight to be increased as compared to nutrients application (38). Minimum 1000-seed weight of 26.38 g was obtained with application of green soil + 25% NPK.

The interaction between varieties and treatments was also shown to have non-significant differed. Maximum 1000-seed weight of 31.20 g was obtained for coarse variety (KSK-133) when plots received recommended dose of green soil. Minimum 1000-seed weight (25.13 g) was recorded for fine variety (PK-386) when plots received recommended dose of NPK.

PADDY YIELD (t ha^{-1})

Paddy yield is presented in Table II. The differences between the varieties were determined to be statistically significant, according to statistical analysis. In compared to fine variety (PK-386), which produced 3.99 t ha^{-1} paddy yield, coarse variety (KSK-133) produced the greater paddy yield (5.56 t ha^{-1}). Variability in yield between rice cultivars is due to genetic features, more vegetative growth of coarse variety and environmental conditions (19).

According to statistical analysis, the differences among the treatments were found to be significant. Table II showed that the recommended amount of NPK resulted in the greatest paddy yield with 5.32 t ha^{-1}. Application of recommended dose of NPK gave higher paddy yield (5, 39-41). However, this yield is statistically similar to 5.30 t ha^{-1} produced by green soil + 50% NPK. Paddy yield of green soil (1.75 kg ha^{-1}) was also found better as well with production of 4.98 t ha^{-1}. Control treatment produced 4.63 t ha^{-1} of paddy yield followed by green soil + 75% NPK whose paddy yield was 4.50 t ha^{-1}. Lowest paddy yield was obtained from green soil + 25% NPK whose production was 3.92 t ha^{-1}.

The interaction between the two factors was determined to be statistically significant. Table II demonstrates that the recommended NPK dose produced the maximum paddy yield when applied to coarse variety (KSK-133), which produced 6.74 t ha^{-1}. Green soil + 50% NPK, followed by green soil + 75% NPK when applied to KSK-133, resulted in better paddy yields of 5.96 and 5.81 t ha^{-1}, respectively. When recommended dose of green soil was applied to coarse variety (KSK-133), resulted in 5.29 t ha^{-1} paddy yield. Minimum paddy yield (3.18 t ha^{-1}) was obtained from fine variety (PK-386), when it received green soil +75% NPK. Recorded data also indicated that green soil @ 1.75 kg ha^{-1} having production of 4.67 t ha^{-1} was statistically at par with green soil + 50% NPK whose paddy yield was 4.63 t ha^{-1} when applied to fine variety (PK-386). Continuous supply of nutrients enables the plants to assimilate adequate photosynthates which is responsible for increased paddy yield (42, 43).

CONCLUSION

According to the findings of this study, nutrient management through the appropriate use of fertilizers in combination with appropriate varieties can play an important role in boosting crop yield and soil fertility. It may be inferred that coarse rice variety (KSK-133) is more suited for increasing paddy production than fine rice variety (PK-386) in Dera Ismail Khan. The coarse variety (KSK-133) produced more tillers and had higher leaf area index throughout the season, that may have resulted in a higher crop growth rate, dry matter accumulation, and 1000-seed weight, ultimately resulting in a higher paddy yield (5.56 t ha^{-1}) than the fine variety (PK-386), which produced a paddy yield of 3.99 t ha^{-1}. Among the fertilizer levels examined, the recommended dose of NPK ranked highest in terms of maximum leaf area index, number of tillers, and minimum sterility (%), which ultimately resulting in highest rice production (5.32 t ha^{-1}). In terms of interaction, a coarse variety (KSK-133) combined with NPK (recommended dose) had been shown to improve plant growth, development as well as rice yield (6.74 t ha^{-1}) under the agro-climatic condition of Dera Ismail Khan. Fine rice variety (PK-386) also performed better as well with application of recommended dose of NPK as compared to other nutrients levels applied to fine rice (PK-386).

Recommendations:

Based on the outcomes of the current research study, it is suggested that coarse rice variety (KSK-133) should be planted along with recommended dose of NPK in agro ecological conditions of Dera Ismail Khan. Keeping in mind the economic importance and high demand of fine rice (PK-386), it is also recommended that fine rice has the potential to produce maximum paddy yield along with recommended dose of NPK may be applied to meet the rice demands of increasing population. As far as *Trichoderma harzianum* L., is concerned, addition of *Trichoderma harzianum* L., may be beneficial to get the desired outcomes because 1.75 kg ha^{-1} didn't show significant results in overall rice production. So, further research on *Trichoderma* *harzianum* L. is required to determine the appropriate dose of *Trichoderma harzianum* L. alone or in combination with different NPK levels.

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