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Impact of Press Mud and Animal Manure in Comparison with NPK on the Growth and Yield of Triticale (*Triticosecale wittmack*) Genotypes Cultivated under Various Irrigation Regimes

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Abstract: It is needful to have alternative nutritious cereal crops to feed the ever increasing population and meet food security in the long run. Triticale (*Triticosecale wittmack*) is used for both livestock feed and human consumption as it contains higher protein and lysine contents than other cereals. Synthetic fertilizers applied in combination with organic amendments can play a pivotal role in increasing crop yields. Field experiments were designed to explore the impact of chemical fertilizers (NPK), press mud and animal manure on growth and yield of triticale genotypes cultivated under different irrigation regimes. Experiments were laid out by using randomized complete block design (RCBD) with split-split plot arrangements having three replicates and comprised of different treatments such as chemical fertilizers (T_1 = control, T_2 = NPK, T_3 = press mud and T_4 = animal manure), genotypes (G_1 and G_2), and irrigation regimes (I_1 = full irrigation, I_2 = irrigation was skipped at heading stage, and I_3 = irrigation was skipped at heading and grain filling stages). Statistical analyses of collected data depicted the significant effect of chemical fertilizers, organic amendments, genotypes and irrigation regimes on various yield and yield related attributes of triticale. The highest increment in various observed attributes like plant height, leaves per plant, spike length, spikelets per spike, grains per spike, leaf area, 1000-grain weight, biological yield and grain yield was recorded in I_1, followed by I_2 and I_3; in case of varieties, G_1 performed better than G_2 while T_3 had maximum values in the aforementioned parameters as compared to other treatments. The application of NPK in combination with press mud and animal manure improved the growth and yield of triticale genotypes cultivated under different irrigation regimes. Thus, NPK along with organic amendments and irrigation practices can successfully be used to improve the growth and yield of triticale.

Keywords: fertilizers; productivity; water requirement; organic amendments; grains; food

1. Introduction

Triticale (*Triticosecale wittmack*) is a new type of real grain crop which was artificially created by a cross between wheat (*Triticum* spp.) and rye (*Secale cereale*) through breeding and selection by a man [1]. Stallknecht et al. [2] reported that initial triticale hybrids were thought to have originated in Scotland in 1875, and the first fertile ones originated in Germany in 1888. At present, triticale is being cultivated on a universal scale, particularly in Central and Eastern Europe, where the principal producers are Poland, Germany, France, Belarus, and Russia [3]. An average triticale has 6% more feed value than corn because of higher lysine content [4]. Dough made from triticale flour is brittle [5], but a triticale flour mixture has been used successfully for making bread and for snack production [5–7]. Products with low gluten levels have been successfully made with triticale flour. Therefore, these flours have been used in the investigational formation of waffles and pancakes, crackers, cakes, and cookies and tortillas [8,9]. If triticale is used for animal feed it should be harvested before the heading stage in order to get good quality fodder [10]. Triticale has greater adoptability to survive under soil salinity, acidity and water stress conditions [11]. The two major effects of abiotic stresses include the impairment of photosynthetic machinery and the unavailability of nutrients. The seedling emergence and growth are significantly affected by the imposition of stress at the early stages of the crop. Abiotic factors such as salt and water are considered as the main stresses which hinder the crop growth [12,13].

Various management approaches are being adapted by the farmers' community to enhance the productivity of agronomic and horticultural crops [14–16], including the intercropping, application of mineral elements, synthetic compounds [17,18], organic amendments [19–21], plant extracts and biostimulants [22,23] via soil, seed coating, seed priming agents and foliar spray [24–26]. To get higher productivity, synthetic fertilizers are considered to be an important input; however, over-dependence on synthetic fertilizers declines soil fertility and crop production with the passage of time [27]. Synthetic fertilizers are faster acting than organic ones, making them a good choice for aiding plants in severe distress from nutrient deficiencies. High and quick doses of nitrogen can specifically contribute to fast plant growth [28]. On the other hand, the acids that synthetic fertilizer contain affect the pH level of the soil. Improperly balanced pH levels negatively affect the overall soil health, potentially killing the beneficial microorganisms that help with natural immunity to infectious diseases [29]. Usage of synthetic fertilizers on degraded soil adversely affects the soil quality and plant growth. This is principally a consequence of low organic matter and less biological activities in the degraded soil along with synthetic fertilizers [30].

The application of organic fertilizers improves the soil structure, which means better infiltration and water-holding capacity [28]. Organic fertilizers can also include beneficial microorganisms in the soil, improving the overall condition of the soil and preventing plant disease [29]. As a substitute of the synthetic fertilizers, organic fertilizers such as poultry manure, sheep manure and farmyard manure can be used to improve the growth, development and yield of crops. In the same way, the application of form yard manure and green manure are the best alternates to improve soil health and crop productivity [31]. Among the organic waste, press mud, known as filter cake, is a byproduct of sugar mills and has different properties such as a soft, elastic, shapeless and dark brown to brownish material. Press mud is considered to have strong surplus effects on soil properties and crop efficiency [32]. Press mud positively influences the physical, chemical, and biological properties of soil, so it is a valuable source of plant nutrients [33]. Organic farming is gaining popularity all over the world. Nearly 4.2 million hectares of land in European countries are now cultivated organically [34,35]. For this purpose, the utilization of various organic wastes might be a helpful practice to meet the requirements of nutrients essential for plant growth. The organic wastes include sewage, sludge and compost [36].

A very limited literature exists about the use of press mud and its effect on the cereal crops and soil of Pakistan. Similarly, regarding irrigation regimes, very little work has been done to examine its impact on the growth and productivity of triticale. Keeping all these features, the present experimentation was designed to determine the impacts of different combinations of press mud, animal manure and NPK fertilizers on growth and yield of the triticale genotypes cultivated under different irrigation regimes.

2. Materials and Methods

2.1. Experimental Description and Crop Management

The field experiments were designed to explore the effects of chemical fertilizers (NPK), press mud and farm yard manure on triticale genotypes cultivated under different irrigation regimes. The field experiments were conducted at the Hafizabad Research Area of the Agronomy Department, Bahauddin Zakariya University, Bahadur sub-campus Layyah, Pakistan, during the triticale cultivation seasons of 2018–2019 and 2019–2020. A soil auger was used to collect the soil samples from different parts of the experimental plot. Standardized protocols and procedures were adopted to determine the physical and chemical characteristics of soil (Table 1). According to soil classification of WBR, experimental soil falls under the aridisols category. The weather data of the experimental station is given in Figure 1.

Table 1. The physical and chemical characteristics of the experimental site.

Parameters	Units	Depth 0–15 cm		Depth 15–30 cm	
Year		2018–19	2019–20	2018–19	2019–20
Soil		Sandy loam			
pH		8.1	7.9	7.95	8
Electrical conductivity	dS m^{-1}	0.89	0.99	1.27	1.21
Organic matter	%	1.43	1.35	1.43	1.41
Total nitrogen	mg kg^{-1}	1.6	1.7	1.5	1.4
Available phosphorous	mg kg^{-1}	9	9.5	9.5	10
Available potassium	mg kg^{-1}	96	92	96	95

Rouni irrigation was done five days before the sowing of triticale. The seedbed was prepared by ploughing the field twice by a tractor mounted cultivator followed by planking. Seeds of triticale genotypes were obtained from Cereal Crop Research Institute (CCRI) Nowshera, Pakistan. Crops were sown manually with a hand drill with a row spacing of 25 cm. Sowing was done in the month of December in 2018 and 2019 for first and second year experiments, respectively. The seed rate of triticale was 150 kg ha^{-1}. The experimental area consisted of 72 plots replicated thrice by keeping net plot size 4 m $\times$ 1 m. Fertilizers were applied at the time of sowing. Hand weeding was performed twice throughout the course of experimentation to control the weed infestation. Disease attack was not observed, so chemicals were not used is this regard. The crop was harvested on 7 May 2019 and 5 May 2020 for the first year and second year of experimentation, respectively.

In the current experimentation, there were three factors under study, including, nutrients resources, triticale genotypes and irrigation regimes.

Factor A-Irrigations
I_1 = Full irrigation
I_2 = Irrigation was skipped at heading stage of triticale
I_3 = Irrigation was skipped at heading plus grain filling stages of triticale
Factor B-Genotypes
V_1 = Genotype –I (LIRON_2/5/DIS B5/3/SPHD/PVN)
V_2 = Genotype-II (POLLMER_2.2.1 $\times$ 2//FARAS/CMH84.4414)
Factor C-Nutrient resources
T_1 = Control (there was no application of fertilizer and any other amendment)
T_2 = N:P:K at the rate of 64:46:25 kg per acre

T_3 = Press mud at the rate of six tons per acre
T_4 = Animal manure at the rate of 6 tons per acre

All fertilizers and organic amendments were applied at sowing time during the experimentation. Urea (46% N), diammonium phosphate (46% P & 18% N), and murate of potash (60% K) were used as sources of nutrients. Major elements present in the press mud were organic matter (210 g kg^{-1}), total nitrogen (20 g kg^{-1}), available phosphorus (13 g kg^{-1}), available potassium (19.5 g kg^{-1}), carbon (4.82 g kg^{-1}), iron (0.32 g kg^{-1}) and zinc (0.12 g kg^{-1}). The electrical conductivity (EC) and pH of press mud were recorded as 2.2 dS m^{-1} and 7.8 respectively. The chemical composition of animal manure was as organic material (82.5%), total nitrogen (3.9%), total phosphorus (0.7%) and total potassium (2.6%). Total five irrigations were applied including rouni irrigation (first irrigation). Other four irrigations were applied at critical crop growth stages of triticale i.e., tillering, stem elongation, heading and grain development stages.

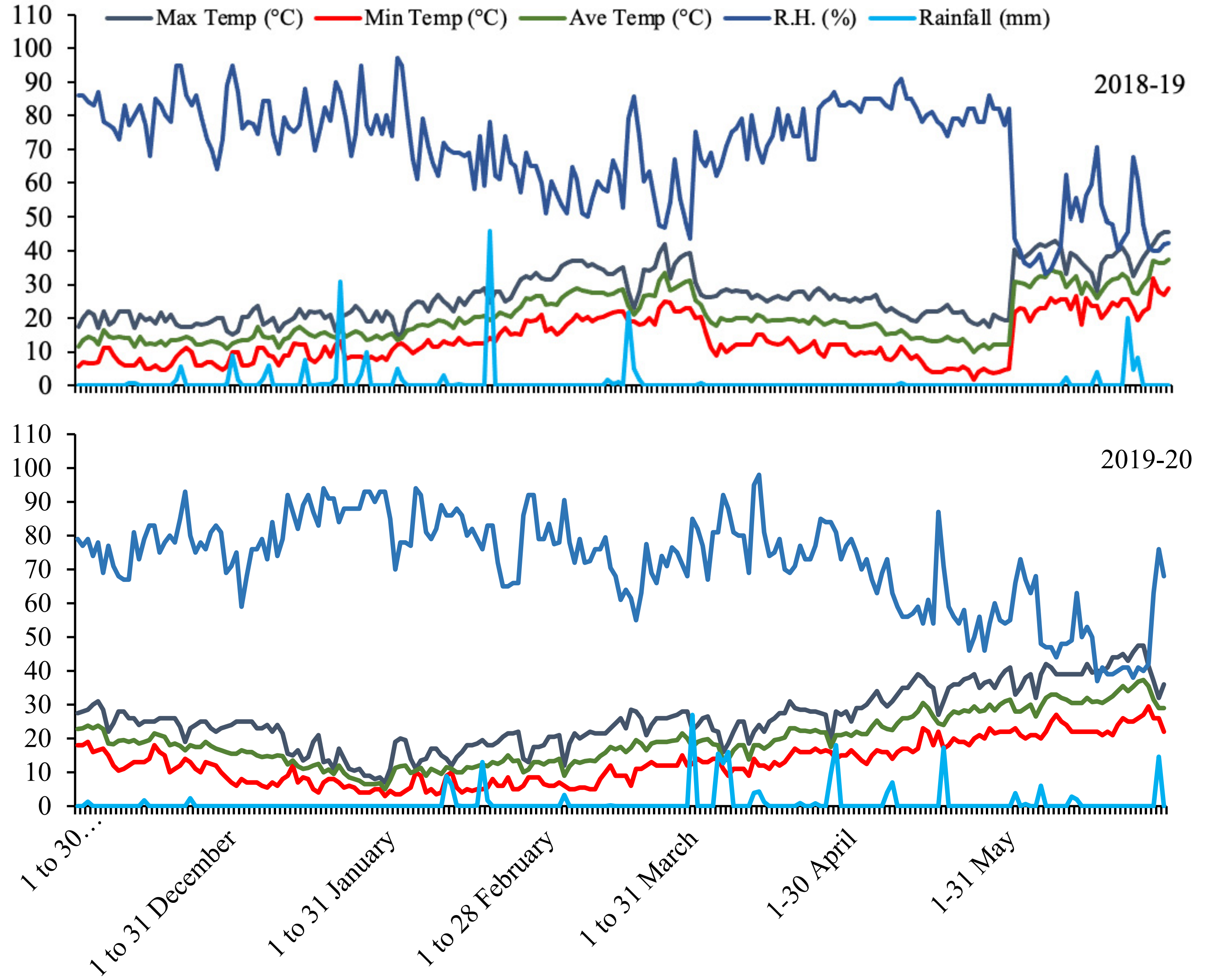

Figure 1. The weather data of experimental station throughout the course of experimentation.

2.2. Estimation of Growth and Yield Attributes

At maturity, the data of growth and yield attributes were recorded. Five plants were randomly selected from each experimental unit to record plant height. Plant height was measured from the base to tip of leaf with the help of meter rod and average of five values was used for further analysis. Spike length was also recorded with the help of a meter rod. Spikelets per spike were counted manually from five randomly selected plants and the average was calculated. The number of grains per spike were counted manually. The leaf area was calculated by taking the length and width of a leaf and using weighted regression equations to get the leaf area. A total of 1000-grains were manually counted from each experiment and weight was measured by a digital weighing balance. The biological yield and grain yield per square meter were recorded with the help of a digital weighing balance and expressed on a ton per hectare basis. The harvest index was estimated as the ratio of grain yield to biological yield using the following formula;

$$\text{Harvest index (\%)} = \text{grain yield/biological yield} \times 100$$

The ratio was multiplied with 100 and the harvest index was expressed in percentage (%).

2.3. Statistical Analysis

The experiment was executed in split-split plot arrangement under randomized complete block design (RCBD) keeping irrigation regimes in main plot, triticale genotypes in subplots and fertilizer treatments in sub-subplots having three replicates. The two seasons' data were tested for homogeneity using Bartlett's test of homogeneity [37], and it was found to be homogeneous, and as a result, the data of both seasons were combined for analysis. The combined analysis of variance (ANOVA) was carried out according to Snedecor and Cochran [38], to estimate the main effects of the different sources of variation and their interactions. An F-test was used to test treatment significance at a 5% probability level using the "MSTAT-C" software package [39]. Mean separation was done using a Tukey's HSD test when significant differences were found.

3. Results

Significance levels of yield and yield related attributes of triticale are presented in Tables 2 and 3. Data related to the impact of irrigation levels, genotypes and treatments on plant height, leaves per plant, spike length, spikelets per spike and grains per spike of triticale are presented in Table 4. Regarding irrigation levels, the highest increment in the foresaid parameters were observed at I_1 followed by I_2 and I_3. In the case of genotypes, G_1 performed better than G_2, while T_3 had maximum values in the foresaid parameters as compared to other treatments (Table 4).

Table 2. Analysis of variance (mean sum of squares) of plant height, spike length, number of leaves per plant, number of spikelets per spike and number of grains per spike of triticale genotypes cultivated under various irrigation regimes in response to NPK and organic amendments.

SOV	DF	Plant Height	Spike Length	Leaves Plant^{-1}	Spikelets Spike^{-1}	Grains Spike^{-1}
Irrigations (I)	2	977.038 **	22.19 **	83.8017 **	320.310 **	4569.20 **
Genotypes (G)	1	15.587 *	6.8388 **	15.6334 **	54.723 **	1054.94 **
Treatments (T)	3	181.412 **	0.2862 *	1.1643 **	1.984 **	74.07 **
I × G	2	14.081 *	0.0527 *	0.1105 *	0.680 *	36.69 **
I × T	6	11.245 **	0.0056NS	0.0065NS	1.057 **	9.17 **
G × T	3	15.423 **	0.0506 *	0.0234 *	1.078 **	3.26 *
I × G × T	6	6.613 *	0.0203 *	0.0188 *	0.224NS	1.34NS

NS = Non-significant, * = Significant at $p \leq 0.05$, ** = Significant at $p \leq 0.01$.

Table 3. Analysis of variance (mean sum of squares) of leaf area, 1000-grain weight, biological yield, grain yield and harvest index of triticale genotypes cultivated under various irrigation regimes in response to NPK and organic amendments.

SOV	DF	Leaf Area	1000-Grain Weight	Biological Yield	Grain Yield	Harvest Index
Irrigations (I)	2	1233.42 **	100.951 **	130,300,000 **	3,516,251 **	136.498 **
Genotypes (G)	1	144.22 **	68.914 **	25,290,000 **	578,709 **	32.232 **
Treatments (T)	3	16.07 **	8.125 **	2,790,220 **	124,662 **	3.928 **
I × G	2	15.38 **	0.429 **	905,643 *	125,490 **	4.723 **
I × T	6	3.32 **	0.234 **	244,559 NS	66,855 **	2.433 **
G × T	3	2.40 **	1.737 **	170,679 NS	23,216 **	0.925 NS
I × G × T	6	1.18 *	0.191 *	326,882 *	33,203 **	1.481 *

NS = Non-significant, * = Significant at $p \leq 0.05$, ** = Significant at $p \leq 0.01$.

Table 4. Impact of NPK and organic amendments on plant height, spike length, number of leaves per plant, number of spikelets per spike and number of gains per spike of triticale genotypes cultivated under various irrigation regimes.

Factors	Plant Height (cm)	Spike Length (cm)	Leaves Plant^{-1} (Number)	Spikelets Spike^{-1} (Number)	Grains Spike^{-1} (Number)
Irrigations (I)					
I1	123.40 a	12.88 a	9.01 a	32.36 a	77.42 a
I2	123.71 a	11.89 b	7.04 b	29.23 b	60.58 b
I3	112.51 b	10.96 c	5.27 c	25.08 c	50.07 c
HSD	1.2608	0.0628	0.0609	0.3175	0.6596
Genotypes (G)					
G1	120.34 a	12.22 a	7.57 a	29.76 a	66.51 a
G2	119.41 b	11.60 b	6.64 b	28.02 b	58.86 b
HSD	0.8548	0.0426	0.0413	0.2153	0.4472
Treatments (T)					
T1	116.84 c	11.74 c	6.78 d	28.56 b	59.93 c
T2	124.23 a	11.91 b	7.03 c	28.94 ab	62.51 b
T3	119.97 b	12.04 a	7.37 a	29.33 a	64.57 a
T4	118.44 bc	11.95 b	7.24 b	28.73 b	63.77 a
HSD	1.6021	0.0798	0.0774	0.4035	0.8382

Means sharing the same letter did not differ significantly at $p = 0.05$.

Data regarding interaction values of irrigation × genotypes, irrigation × treatments and genotypes × treatments of plant height, leaves per plant, spike length, spikelets per spike and grains per spike of triticale are presented in Table 5. Interaction between irrigation levels and varieties showed the highest increase in foresaid attributes at I1G1 while the lowest values were recorded at I_3G_2 (Table 5). In case of the interaction between irrigation levels and treatments, maximum increase in plant height was observed at I_1T_2, which is statistically similar to I_2T_1 and I_2T_2 while the minimum value was at I_3T_1 (Table 5). In case of leaves per plant and spike length, the interaction between irrigation levels and treatments was non-significant (Table 5). In case of spikelets per spike, the highest value was recorded at I_1T_2, which is statistically similar to I_1T_3 and I_1T_4, while the lowest number of spikelets per spike was observed at I_3T_4 (Table 5). The maximum value of grains per spike was at I_1T_3, which is statistically similar to I_1T_4, while the minimum value was at I_3T_1

(Table 5). In case of interactions between varieties and treatments, a maximum increase in plant height was observed at G_2T_2 which is statistically similar to G_1T_2, while the minimum value was at G_2T_1 (Table 5). In case of leaves per plant, spike length, spikelets per spike and grains per spike of triticale, the highest increment in said parameters was observed at G_1T_3, while the lowest value was recorded at G_2T_1 (Table 5).

Table 5. Interactive response of two factors regarding plant height, spike length, number of leaves per plant, number of spikelets per spike and number of gains per spike of triticale genotypes.

Factors	Plant Height (cm)	Spike Length (cm)	Leaves Plant^{-1} (Number)	Spikelets Spike^{-1} (Number)	Grains Spike^{-1} (Number)
Interaction of irrigations and genotypes (I × G)					
I1G1	124.48 ^{a}	13.24 ^{a}	9.54 ^{a}	33.32 ^{a}	82.67 ^{a}
I1G2	122.32 ^{a}	12.52 ^{b}	8.47 ^{b}	31.39 ^{b}	72.18 ^{b}
I2G1	124.42 ^{a}	12.15 ^{c}	7.51 ^{c}	30.21 ^{c}	63.85 ^{c}
I2G2	123.01 ^{a}	11.63 ^{d}	6.57 ^{d}	28.26 ^{d}	57.32 ^{d}
I3G1	112.12 ^{b}	11.26 ^{e}	5.67 ^{e}	25.76 ^{e}	53.04 ^{e}
I3G2	112.90 ^{b}	10.65 ^{f}	4.87 ^{f}	24.40 ^{f}	47.09 ^{f}
HSD	2.1883	0.1091	0.1057	0.5511	1.1449
Interaction pf irrigation and treatments (I × T)					
I1T1	119.90 ^{b}	12.68	8.65	31.69 ^{b}	72.65 ^{c}
I1T2	128.78 ^{a}	12.87	8.92	32.72 ^{a}	77.35 ^{b}
I1T3	123.40 ^{b}	13.05	9.30	32.57 ^{ab}	80.43 ^{a}
I1T4	121.52 ^{b}	12.92	9.15	32.47 ^{ab}	79.25 ^{a}
I2T1	128.78 ^{a}	11.76	6.72	29.42 ^{cd}	58.53 ^{e}
I2T2	129.23 ^{a}	11.88	6.97	28.77 ^{d}	60.38 ^{de}
I2T3	122.58 ^{b}	11.98	7.32	29.68 ^{c}	61.88 ^{d}
I2T4	122.30 ^{b}	11.94	7.15	29.06 ^{cd}	61.55
I3T1	109.90 ^{d}	10.78	4.98	24.56 ^{f}	48.60 ^{g}
I3T2	114.68 ^{c}	10.97	5.20	25.35 ^{ef}	49.78 ^{fg}
I3T3	113.93 ^{c}	11.09	5.48	25.73 ^{e}	51.38 ^{f}
I3T4	111.52 ^{cd}	10.98	5.42	24.67 ^{f}	50.50 ^{f}
HSD	3.5804	0.1784	0.1729	0.9017	1.8732
Interaction of genotypes and treatments (G × T)					
G1T1	117.60 ^{de}	11.99 ^{c}	7.29 ^{c}	29.07 ^{b}	63.18 ^{c}
G1T2	123.43 ^{ab}	12.18 ^{b}	7.51 ^{b}	30.02 ^{a}	66.28 ^{b}
G1T3	121.38 ^{bc}	12.38 ^{a}	7.80 ^{a}	30.28 ^{a}	68.66 ^{a}
G1T4	118.94 ^{cd}	12.31 ^{ab}	7.68 ^{a}	29.67 ^{ab}	67.97 ^{a}
G2T1	116.09 ^{e}	11.49 ^{e}	6.28 ^{g}	28.04 ^{c}	56.68 ^{f}
G2T2	125.03 ^{a}	11.63 ^{d}	6.54 ^{f}	27.87 ^{c}	58.73 ^{e}
G2T3	118.57 ^{de}	11.70 ^{d}	6.93 ^{d}	28.38 ^{c}	60.48 ^{d}
G2T4	117.94 ^{de}	11.57 ^{de}	6.80 ^{e}	27.79 ^{c}	59.57 ^{de}
HSD	2.6975	0.1344	0.1303	0.6793	1.4113

Means sharing the same letter did not differ significantly at $p = 0.05$.

Data regarding the interaction values of irrigation levels × genotypes × treatments of plant height, leaves per plant, spike length, spikelets per spike and grains per spike of triticale are presented in Table 6. A maximum increase in plant height was observed at $I_2G_1T_2$, which is statistically similar to $I_1G_2T_2$ and $I_2G_2T_2$, while the minimum value was at $I_3G_2T_1$ (Table 6). In case of spike length, maximum spike length was at $I_1G_1T_3$, which is statistically similar to $I_1V_1T_4$, while the minimum value of spike length was recorded at $I_3G_2T_1$ (Table 6). A trend similar to spike length was observed in the case of the number of leaves per plant of triticale while a non-significant effect regarding spikelets per spike and grains per spike was recorded (Table 6). Data related to the impact of irrigation levels, varieties and treatments on the leaf area, 1000-grain weight, biological yield, grain yield and harvest index of triticale are presented in Table 7. Regarding irrigation levels, the highest increment in foresaid parameters except harvest index were observed at I_1 followed by I_2 and I_3, respectively. In case of varieties, G_1 performed better than G_2 in all parameters except harvest index, while T_3 had maximum values in the mentioned parameters as compared to other treatments (Table 7).

Table 6. Interactive response of all factors regarding plant height, spike length, number of leaves per plant, number of spikelets per spike and number of gains per spike of triticale genotypes.

Factors	Plant Height (cm)	Spike Length (cm)	Leaves Plant^{-1} (Number)	Spikelets Spike^{-1} (Number)	Grains Spike^{-1} (Number)
Interaction of irrigations, genotypes and treatments (I × G × T)					
I1G1T1	121.37 ^{def}	12.90 ^{c}	9.22 ^{c}	32.27	76.67
I1G1T2	128.33 ^{ab}	13.17 ^{bc}	9.43 ^{bc}	33.77	82.37
I1G1T3	125.80 ^{abcd}	13.50 ^{a}	9.80 ^{a}	33.70	86.53
I1G1T4	122.43 ^{def}	13.37 ^{ab}	9.70 ^{ab}	33.57	85.10
I1G2T1	118.43 ^{efgh}	12.47 ^{de}	8.10 ^{f}	31.12	68.63
I1G2T2	129.23 ^{a}	12.57 ^{d}	8.40 ^{e}	31.67	72.33
I1G2T3	121.00 ^{def}	12.60 ^{d}	8.80 ^{d}	31.43	74.33
I1G2T4	120.60 ^{def}	12.47 ^{de}	8.60 ^{de}	31.37	73.40
I2G1T1	121.17 ^{def}	11.98 ^{gh}	7.20 ^{i}	29.90	61.47
I2G1T2	130.33 ^{a}	12.14 ^{fg}	7.43 ^{hi}	29.93	63.70
I2G1T3	123.53 ^{bcde}	12.27 ^{ef}	7.77 ^{g}	30.67	65.23
I2G1T4	120.60 ^{def}	12.23 ^{efg}	7.63 ^{gh}	30.32	65.00
I2G2T1	120.30 ^{defg}	11.53 ^{ijk}	6.23 ^{l}	28.93	55.60
I2G2T2	128.13 ^{abc}	11.63 ^{ij}	6.50 ^{kl}	27.60	57.07
I2G2T3	121.63 ^{def}	11.70 ^{hi}	6.87 ^{j}	28.70	58.53
I2G2T4	121.97 ^{def}	11.66 ^{ij}	6.67 ^{jk}	27.80	58.10
I3G1T1	110.27 ^{i}	11.10 ^{m}	5.47 ^{n}	25.06	51.40
I3G1T2	111.63 ^{i}	11.23 ^{lm}	5.67 ^{mn}	26.37	52.77
I3G1T3	114.80 ^{ghi}	11.39 ^{jkl}	5.83 ^{m}	26.47	54.20
I3G1T4	111.77 ^{i}	11.33 ^{klm}	5.70 ^{mn}	25.13	53.80
I3G2T1	109.53 ^{i}	10.47 ^{o}	4.50 ^{p}	24.07	45.80
I3G2T2	117.73 ^{fgh}	10.70 ^{no}	4.73 ^{p}	24.33	46.80
I3G2T3	113.07 ^{hi}	10.80 ^{n}	5.13 ^{o}	25.00	48.57
I3G2T4	111.27 ^{i}	10.63 ^{no}	5.13 ^{o}	24.20	47.20
HSD	5.6816	0.2832	0.2744	1.4309	2.9726

Means sharing the same letter did not differ significantly at $p = 0.05$.

Table 7. Impact of NPK and organic amendments on leaf area, 1000-grain weight, biological yield, grain yield and harvest index of triticale genotypes cultivated under various irrigation regimes.

Factors	Leaf Area (cm^2)	1000-Grain Weight (g)	Biological Yield ($kg\ ha^{-1}$)	Grain Yield ($kg\ ha^{-1}$)	Harvest Index (%)
Irrigations (I)					
I1	33.62 ^{a}	40.22 ^{a}	15,787 ^{a}	4340.8 ^{a}	27.51 ^{c}
I2	24.35 ^{b}	38.28 ^{b}	13,281 ^{b}	3878.5 ^{b}	29.27 ^{b}
I3	19.51 ^{c}	36.12 ^{c}	11,131 ^{c}	3581.3 ^{c}	32.23 ^{a}
HSD	0.4739	0.1781	232.25	42.708	0.5414
Genotypes (G)					
G1	27.24 ^{a}	39.18 ^{a}	13,992 ^{a}	4023.2 ^{a}	29.01 ^{b}
G2	24.41 ^{b}	37.23 ^{b}	12,807 ^{b}	3843.9 ^{b}	30.34 ^{a}
HSD	0.3213	0.1207	157.46	28.956	0.3671
Treatments (T)					
T1	24.63 ^{c}	37.32 ^{c}	12,872 ^{c}	3851.7 ^{c}	30.31 ^{a}
T2	25.59 ^{b}	38.31 ^{b}	13,326 ^{b}	3888.9 ^{c}	29.49 ^{b}
T3	26.83 ^{a}	38.95 ^{a}	13,718 ^{a}	4041.9 ^{a}	29.68 ^{ab}
T4	26.26 ^{a}	38.29 ^{b}	13,683 ^{a}	3951.7 ^{b}	29.21 ^{b}
HSD	0.6022	0.2263	295.12	54.270	0.6879

Means sharing the same letter did not differ significantly at $p = 0.05$.

Data regarding the interaction values of irrigation × genotypes, irrigation × treatments and genotypes × treatments of leaf area, 1000-grain weight, biological yield, grain yield and harvest index of triticale are presented in Table 8. The interaction between irrigation levels and varieties showed the highest increase in the leaf area, 1000-grain weight, biological yield and grain yield at I_1G_1, while the lowest values were recorded at I_3G_2 (Table 8). In case of harvest index, the maximum value was in the case of I_3G_2, while the minimum value was observed at I_1G_1 (Table 8). In case of the interaction between irrigation levels and treatments, the highest values of leaf area, 1000-grain weight and grain yield were observed at I_1T_3, while the lowest values of foresaid attributes were at I_3T_4 (Table 8). The interaction between irrigation levels and treatments for biological yield was non-significant, while the highest increment in harvest index was at I_3T_1, while the lowest values were recorded at I_1T_4 (Table 8). In case of the interaction between varieties and treatments, the maximum increase in leaf area, 1000-grain weight and grain yield was observed at G_1T_3, while the minimum values of the foresaid attributes were at G_2T_1 (Table 8). The interaction between varieties and treatments for biological yield and harvest index was non-significant (Table 8).

Table 8. Interactive response of two factors regarding leaf area, 1000-grain weight, biological yield, grain yield and harvest index of triticale genotypes.

Factors	Leaf Area (cm^2)	1000-Grain Weight (g)	Biological Yield (kg ha^{-1})	Grain Yield (kg ha^{-1})	Harvest Index (%)
Interaction of irrigations and genotypes (I × G)					
I1G1	35.91 ^{a}	41.21 ^{a}	16,493 ^{a}	4508.3 ^{a}	27.35 ^{e}
I1G2	31.32 ^{b}	39.23 ^{b}	15,082 ^{b}	4173.3 ^{b}	27.67 ^{de}
I2G1	25.57 ^{c}	39.12 ^{b}	13,985 ^{c}	3955.4 ^{c}	28.30 ^{d}
I2G2	23.12 ^{d}	37.44 ^{c}	12,577 ^{d}	3801.7 ^{d}	30.25 ^{c}
I3G1	20.24 ^{e}	37.23 ^{c}	11,499 ^{e}	3605.8 ^{e}	31.36 ^{b}
I3G2	18.78 ^{f}	35.02 ^{d}	10,762 ^{f}	3556.7 ^{e}	33.11 ^{a}
HSD	0.8225	0.3091	403.11	74.128	0.9397
Interaction pf irrigation and treatments (I × T)					
I1T1	31.40 ^{c}	39.47 ^{c}	15,122	4160.0 ^{c}	27.52 ^{def}
I1T2	33.15 ^{b}	40.12 ^{b}	15,508	4226.7 ^{c}	27.26 ^{ef}
I1T3	35.32 ^{a}	41.17 ^{a}	16,217	4615.0 ^{a}	28.46 ^{cde}
I1T4	34.61 ^{a}	40.14 ^{b}	16,302	4361.7 ^{b}	26.82 ^{f}
I2T1	23.36 ^{e}	37.45 ^{f}	12,737	3810.0 ^{d}	29.99 ^{c}
I2T2	24.19 ^{de}	38.38 ^{e}	13,408	3875.0 ^{d}	28.94 ^{cd}
I2T3	25.38 ^{d}	38.90 ^{d}	13,607	3924.2 ^{d}	28.92 ^{cd}
I2T4	24.45 ^{de}	38.38 ^{e}	13,372	3905.0 ^{d}	29.26 ^{c}
I3T1	19.13 ^{f}	35.03 ^{i}	10,758	3585.0 ^{e}	33.43 ^{a}
I3T2	19.41 ^{f}	36.42 ^{gh}	11,060	3565.0 ^{e}	32.28 ^{ab}
I3T3	19.78 ^{f}	36.78 ^{g}	11,330	3586.7 ^{e}	31.67 ^{b}
I3T4	19.72 ^{f}	36.26 ^{h}	11,375	3588.3 ^{e}	31.56 ^{b}
HSD	1.3458	0.5057	659.56	121.29	1.5375
Interaction of genotypes and treatments (G × T)					
G1T1	25.78 ^{bc}	38.01 ^{c}	13,539	3938.9 ^{bc}	29.33
G1T2	26.65 ^{b}	39.33 ^{b}	13,792	3948.9 ^{bc}	28.87
G1T3	28.63 ^{a}	40.34 ^{a}	14,390	4182.8 ^{a}	29.24
G1T4	27.91 ^{a}	39.06 ^{b}	14,248	4022.2 ^{b}	28.59
G2T1	23.48 ^{e}	36.63 ^{e}	12,206	3764.4 ^{e}	31.29
G2T2	24.52 ^{d}	37.28 ^{d}	12,859	3828.9 ^{de}	30.12
G2T3	25.03 ^{cd}	37.56 ^{d}	13,046	3901.1 ^{cd}	30.13
G2T4	24.61 ^{d}	37.46 ^{d}	13,118	3881.1 ^{cd}	29.83
HSD	1.0139	0.3810	496.91	91.377	1.1583

Means sharing the same letter did not differ significantly at $p = 0.05$.

Data regarding interaction values of irrigation levels × genotypes × treatments of leaf area, 1000-grain weight, biological yield, grain yield and harvest index of triticale are presented in Table 9. The highest increment in leaf area, 1000-grain weight, biological yield and grain yield was recorded at $I_1G_1T_3$ while the lowest values were recorded at $I_3G_2T_1$ (Table 9). The maximum value of the harvest index was at $I_3G_2T_1$, while the minimum value was at $I_1G_1T_4$ (Table 9).

Table 9. Interactive response of all factors regarding leaf area, 1000-grain weight, biological yield, grain yield and harvest index of triticale genotypes.

Factors	Leaf Area (cm^2)	1000-Grain Weight (g)	Biological Yield (kg ha^{-1})	Grain Yield (kg ha^{-1})	Harvest Index (%)
Interaction of irrigations, genotypes and treatments (I × G × T)					
I1G1T1	33.35 ^{bc}	40.10 ^{de}	15,643 ^{bc}	4270.0 ^{c}	27.29 ^{ghi}
I1G1T2	34.55 ^{b}	41.30 ^{b}	15,907 ^{b}	4303.3 ^{c}	27.05 ^{hi}
I1G1T3	38.13 ^{a}	42.53 ^{a}	17,197 ^{a}	4950.0 ^{a}	28.82 ^{efgh}
I1G1T4	37.61 ^{a}	40.93 ^{bc}	17,223 ^{a}	4510.0 ^{b}	26.24 ^{i}
I1G2T1	29.45 ^{d}	38.84 ^{gh}	14,600 ^{cde}	4050.0 ^{def}	27.05 ^{hi}
I1G2T2	31.75 ^{c}	38.93 ^{gh}	15,110 ^{bcd}	4150.0 ^{cde}	27.47 ^{ghi}
I1G2T3	32.50 ^{bc}	39.80 ^{def}	15,237 ^{bcd}	4280.0 ^{c}	28.09 ^{fghi}
I1G2T4	31.60 ^{c}	39.34 ^{efg}	15,380 ^{bcd}	4213.3 ^{cd}	27.39 ^{ghi}
I2G1T1	24.08 ^{fgh}	38.23 ^{hi}	13,567 ^{ef}	3930.0 ^{fg}	28.98 ^{efgh}
I2G1T2	25.29 ^{efg}	39.03 ^{fgh}	14,030 ^{e}	3970.0 ^{efg}	28.30 ^{fghi}
I2G1T3	27.25 ^{e}	40.23 ^{cd}	14,357 ^{de}	3968.3 ^{efg}	27.64 ^{ghi}
I2G1T4	25.67 ^{ef}	38.97 ^{gh}	13,987 ^{e}	3953.3 ^{fg}	28.28 ^{fghi}
I2G2T1	22.63 ^{h}	36.67 ^{k}	11,907 ^{gh}	3690.0 ^{hij}	30.99 ^{bcde}
I2G2T2	23.09 ^{h}	37.73 ^{ij}	12,787 ^{fg}	3780.0 ^{ghi}	29.57 ^{defg}
I2G2T3	23.52 ^{gh}	37.57 ^{ij}	12,857 ^{fg}	3880.0 ^{fgh}	30.20 ^{cdef}
I2G2T4	23.24 ^{gh}	37.80 ^{ij}	12,757 ^{fg}	3856.7 ^{gh}	30.23 ^{cdef}
I3G1T1	19.89 ^{i}	35.70 ^{l}	11,407 ^{hi}	3616.7 ^{ij}	31.71 ^{bcd}
I3G1T2	20.11 ^{i}	37.67 ^{ij}	11,440 ^{hi}	3573.3 ^{j}	31.24 ^{bcde}
I3G1T3	20.49 ^{i}	38.27 ^{hi}	11,617 ^{hi}	3630.0 ^{ij}	31.25 ^{bcde}
I3G1T4	20.45 ^{i}	37.27 ^{jk}	11,533 ^{hi}	3603.3 ^{ij}	31.24 ^{bcde}
I3G2T1	18.37 ^{i}	34.37 ^{m}	11,440 ^{hi}	3553.3 ^{j}	35.15 ^{a}
I3G2T2	18.72 ^{i}	35.17 ^{lm}	10,680 ^{ij}	3556.7 ^{j}	33.32 ^{ab}
I3G2T3	19.07 ^{i}	35.30 ^{l}	11,043 ^{hij}	3543.3 ^{j}	32.08 ^{bc}
I3G2T4	18.98 ^{i}	35.24 ^{l}	11,217 ^{hi}	3573.3 ^{j}	31.87 ^{bcd}
HSD	2.1356	0.8024	1046.6	192.47	2.4398

Means sharing the same letter did not differ significantly at $p = 0.05$.

4. Discussion

The frequency of irrigation and its time of application is very crucial for the growth and development of crop plants, as they are linked with economic yield. In the current experimentation, skipping irrigation reduced plant height, number of leaves and all other related parameters of both genotypes, but maximum reduction in plant height and all other parameters were observed when irrigation was skipped at the heading and grain filling stage. In the case of water stress, plant growth and development was reduced as a result of poor root development and reduced foliage-surface characters such as its form, shape and composition. Triticale is a potential cereal crop to give better yield under moister stressed condition. It is supported by previous studies that drought had little effect on all parameters, as plants initiated defense mechanisms against water deficiency [40,41]. The negative effects of water stress on plant height, grain yield and all other parameters concurred with the results of past studies. Plant growth processes could be disturbed when the plant faced water stressed conditions, and as a result it leads to maximum variations among the protein contents of grain and grain yields [42]. These findings are in line with the outcomes of Qamar et al. [43], who reported that water stress reduced the yield and its related parameters in wheat. At maturity stage, which was observed as the period between blossoming and harvest was also delayed when drought appeared after flowering. Genotypes showed potential against drought stress and they were escaped from drought so there is a difference in plant water status due to which delay in maturity was observed in genotypes during water stress. According to Basal and Szabo [44], drought stress is responsible for the reduction in the yield of field crops. There are many genes in cereal crops which respond under abiotic stresses. particularly in drought stress [45].

NPK influences the plant height and grain yield as compared to control but failed under drought stress as NPK has no water holding capacity. Mineral fertilization plays a critical role in crop growth and productivity [46,47]. On the other hand, the organic manure and/or press mud increased the resistance to water stress. The maximum number of grains per spike were observed with press mud application even in drought stress, as press mud increased the water holding capacity and also increased the nutrient availability. The influence of press mud and farm yard manure fertilization on 1000 grain weight was highly significant statistically [48]. These outcomes are supported by Zahid et al. [49], that organic amendments along with mineral nutrition not only increase growth and yield attributes but also improve the fertility status of soil. The application of urea and poultry manure either alone or in combination significantly affected cucumber growth, yield and postharvest quality. Among integrated treatments, the application of urea at a rate of 90 kg N ha^{-1} and poultry manure at a rate of 30 kg N ha^{-1} showed about a 26% increase in plant height, a 30% increase in leaf area, and a 32% increase in the number of leaves per plant. Similarly, fruit weight, postharvest quality and N uptake efficiency were also increased.

Seed size is of great importance in plant growth and yield parameter, the information about the effects of seed size on plant growth in water and salt stress is limited in triticale. Water deficiency is also supplemented by the hydrolytic decomposition of carbohydrates as at the final stage of seed maturity, the content of monosaccharaides decreases. And if we see the interaction between drought and organic amendments press mud with a dose of 20 tons ha^{-1} caused a significant increase in the grain yield of the both genotype of winter triticale. These findings are supported by Sarwar et al. [50], who explained that organic amendments are responsible for the higher yield of maize hybrids because nutrients are available throughout the growth period of a crop. Press mud and farm yard manure also performed well even in drought conditions, which supports the earlier studies conducted by other authors, who reported that organic matter in soil expands soil structures, nutrient preservation, exposure to air, soil water holding capacity and water penetration [20,51]. Drought stress adversely affects growth and the yield of grain and fruits crops [52,53]. Competition between soil microorganisms and plants for nutrients occurred by plant nutrient uptake as a result of highly organic matter decomposition as provided by organic amendments for availability of plant nutrients [54]. The yield and quality of triticale significantly varied across the treatments. According to Dekic et al. [55] and Rajicic et al. [48], combined usage of NPK fertilizer (80 kg N ha^{-1}, 100 kg P_2O_5 ha^{-1} and 60 kg K_2O ha^{-1}) represented an excellent base for the optimum supply of major nutrients, resulting in maximum grain yield. Water absorbed by plant roots and water condition in plant tissues is estimated by a balance due to which leaf extension could be limited due water stress in plants [56]. It was suggested by Blum [57] to avoid dehydration, small leaf area is valuable in case of water stress. However, in the case of PM and NPK, the leaf area is less affected as a consequence of more moisture being retained in the soil. Finally, it is estimated that organic amendments have more advantages than inorganic fertilizers, as organic fertilizers performed best in drought stress conditions. They are not harmful for our environment and have long lasting effects.

5. Conclusions

The application of chemical fertilizers (NPK), press mud and animal manure improved yield and yield related attributes of triticale genotypes cultivated under different irrigation regimes. However, G_1 performed better than G_2. Regarding various irrigation regimes, the maximum increase in yield and yield related attributes was observed in the case of full irrigation, while the application of press mud showed better results than other treatments. It is concluded from the outcomes of the current experiment that chemical fertilizers in combination with organic amendments and irrigation practices successfully enhanced the productivity of triticale genotypes.

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