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Screening For Drought-Tolerant Tropical Wheat Varieties Using Different Indices

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ABSTRACT
Wheat crop (*Triticum aestivum* L) is one of the most important crops in the world, feeding more than 50% of the population. Wheat production in most producing states in Nigeria is seriously affected by abiotic stress, especially drought. Hence understanding which morphological traits will be instrumental for yield increase will help. This study aims to evaluate, screen, and identify drought-tolerant varieties in different tropical wheat varieties grown under normal and water stress conditions using different drought-tolerant indices. The experiment was laid using a split-plot design with three irrigation levels as the main plot and 10 wheat varieties as sub-plots, replicated three times. Results show that irrigation treatment has a significant effect on the performance of all the varieties. Among all the varieties, KAUZ-9 and TEVEE'S proved to be more tolerant than others by showing little differences between their yield under normal and stress conditions and are therefore recommended for use in the savannah one of Nigeria.
Keywords: Drought, Tropical wheat, Yield, Screening

INTRODUCTION

Climate changes have decreased the amount of water in the soil for the plants to utilize. This has made the production of stable crop food like wheat very difficult in some areas (Ahmed *et al* 2019). It was reported that about 50% of whet yield is lost annually in many wheat developing regions due to water stress conditions (Gavuzzi *et al*., 1997). The situation became more worrisome with the recent report of decreasing amount of water in the soil as a result of over-exploitation of the water for irrigation activities (Hafiz *et al*., 2020). This has caused a serious problem to food insecurity, especially in developing countries.

Wheat crop is important among the cereal because of its nutritional values, today wheat is feeding more population than any cereal crop. The growth in populations and lifestyle changes has increased the demand for wheat. This has posed a challenge to scientists and breeders to create new wheat cultivars with promising yields using less amount of water (Mujtaba *et al*., 2016). Identification and development of drought-tolerant genotype is one of the wheat breeding program's challenges worldwide (Seyed *et al*., 2013). It is important to understand the water requirements of the existing wheat varieties and study the mechanisms and behavior of the varieties under a water deficit environment. This will provide a way of identifying wheat varieties that will yield under water deficit conditions (Fokion *et al*., 2015). The water stress tolerance mechanism in plants is a complex network (Zhu *et al*., 2016). It involves different changes at different developmental stages of the plants (Saeidi and Abdoli, 2018). Therefore, screening these varieties for water stress tolerance under different irrigation regimes will provide an insight into the drought tolerance ability of the varieties.

The ability of crops to perform relatively well under water stress is an important indicator that can be used to select drought tolerance crop variety, some drought indices have been suggested as a way of selecting drought tolerance varieties using a mathematical formula to calculate the difference between yield in stress and non-stress environment, these indices can be used to classified drought resistance and susceptible varieties (Raman *et al*., 2012). Drought resistance indices such as stress susceptibility index (SSI), drought relative index (DRI), yield stability index (YSI), stress tolerance (TOL), and many more have been used in previous studies to show how resistant a cultivar is to water stress (Khan and Dhurve, 2016; Pantuwan *et al*., 2002, Ouk *et al*., 2006; Sio-Se Mardeh *et al*., 2006). Rosielle and Hamblin (1981) proposed and defined TOL as the difference between yield under stress condition and non-stress (Yp) condition. Mean productivity (MP) is the average yield of Ys and Yp. While Fischer and Maurer (1978), proposed Geometric mean productivity (GMP), which shows the relative performance of genotypes under various conditions. Fernandez (1993), defined a new advanced index; stress tolerance index (STI), which can be used to identify genotypes that produce high yield under both stress and non-stress conditions. Sayed *et al*, (2013), used RDI and SSI for the evaluation of drought tolerance in wheat genotypes, SSI higher than one indicates above-average susceptibility to drought stress. Bouslama, and Schapaugh (1984), propose the use of YSI. This is calculated for a given genotype using grain yield under stress conditions relative to its grain yield under non-stressed conditions.

This study aimed to evaluate, screen, and identify drought-tolerant variety in different tropical wheat varieties grown under normal and water stress conditions using different drought-tolerant indices.

MATERIALS AND METHODS

Study Site

The study was conducted at the Abubakar Tafawa Balewa University Bauchi. Bauchi State is situated in the northeast zone of Nigeria. Geographically the state is located between latitudes 9°30' and 12°30' North of the equator and between longitudes 8°45' and 11°0' East of the Greenwich meridian (GPS Coordinates).

Source of Seeds

A set of ten (10) tropical wheat variety seeds were used, these varieties were originated, tested, and released in Nigeria by Lake Chad research institute (LCRI) in Borno state Nigeria. The pedigree of the seeds is shown in Table (1), these seeds have been widely accepted by wheat farmers in the region because they are available and affordable to the farmers.

Table 1: Seeds entry number pedigree and color

Entry Number	Pedigree	Seed Color
901	VEE7/KAUZ/9/CHUM/8/7*BCN (AISBW05-0011-13AP-0AP-7AP-0SD)	White
902	VEE/NAC//REBWAH-19(ICW06-00354-1AP-0AP-7AP-0SD)	White
903	SERI 82/SHUWA'S'//GRU90-204782/3/MUNIA/CHTO//MILAN (AISBW05-0252-1AP-0AP-0AP-1AP-0SD)	White
904	ATTILA 50Y//ATTILA/BCN/3/STAR*3/MUSK-3(AISBW05-0043-10AP-OAP-0AP-7AP)	White
905	IMAM (CM85836-50Y-0M-0Y-3M-0Y-0SY-0AP)	White
906	GOUMRIA-3[VEE#7/KAUZ'S'](ICW94-0029-0L-1AP-7AP-0AP-0SDN)	White
907	USHER-18 (CROW'S'/BOW'S'-1994/95//ASFOOR-5)	White
908	ATTILA 7/3/PYN/BAU//MILAN/5/KAUZ/3/MYN (ICW06-50361-1AP-0AP-0AP-0SD-4SD-0SD)	White
909	ATTILA 7/3/PYN/BAU//MILAN/5/KAUZ/3/MYN (ICW06-50361-1AP-0AP-0AP-0SD-4SD-0SD)	White
910	NORMAN [RSM-NORMAN F2008] BABAX/LR42/BARAX (CGSS96 BO2235-099 B-019Y-22B-OY-58B-OM-03CJ-03T-OMX) (Improved Check)	RED

Experimental Design

The experiment was laid using a split-plot design. Irrigation scheduling was the main plot, while variety is the subplot. The land was cleared, plowed, harrowed, leveled and plots measuring 1.5 x 3m were constructed with wide water channels in between each main plot. Each net plot consists of 4 rows of 3m long with 25cm space between row and 15 cm spacing within the plot. 1m and 1.5m spacing was maintained between treatments and replicates respectively. Planting was done on the 15th of November for two seasons, that is the 2018/2019 and 2019/2020 dry farming season. The seeds sowing was at the rate of 120 kg/ha using hand drilling at 2-3 cm depth as done by (Sokoto and Abubakar, 2015). After sowing, all plots were irrigated with 15 liters of water immediately for the proper establishment of the seedlings as done by Lado, (2004). Check basin irrigation method was used; subsequently watering was done following the irrigation treatment i.e., irrigation after 5 days intervals (non-stress condition) and irrigation after 15 days intervals (a stress condition). Weeds were removed manually with the hand at certain intervals. All agronomic practices used in the wheat-growing field were strictly followed in all the plots.

Data Collection

Determination of yield and yield-related traits

Ten (10) plants were randomly selected from the two middle rows and tagged for the recording of the following traits from all the plots:

1. **The number of spikes per plot**: These were determined by counting all spikes from the tagged plants from each plot.

2. **The number of grains per spike (NGS)**: was counted from the spikes of the tagged sample plants that were used to determine the previous parameters.
3. **Spike Length (cm)**: this was measured using a meter ruler from the base to the tip of the spike excluding awns at maturity.
4. **Weight of 1000 grains (TGW)**: was determined by weighing 1000 seed grains from the tagged sample plants at each plot and recording it in kg.
5. **Grain Yield (t/ha)**: was achieved by weighing the seed from each plot and expressed into hectare in kilogram before converting it into tons per hectare (t/h)

Drought tolerance indices.

Drought tolerance indices were calculated using the yield difference between stress and non-stress condition. The following mathematical formula was used in the calculations

- **Stress Tolerance Index STI** = $[(Yp) \times / (\bar{Y}p)^{2}$
- **Mean Productivity MP** = $(Yp + Ys) / 2$
- **Geometric Mean Productivity GMP** = $[(Yp)^{0.5}$
- **Stress Tolerance TOL** = $(Yp - Ys)$
- **Stress Intensity SI** = $1 - [(\bar{Y}s) / (\bar{Y}p)]$
- **Stress Susceptibility Index SSI** = $1 - [(Yp)] / SI$
- **Yield Stability Index YSI** = Ys / Yp
- **Relative drought index RDI** = $(Ys / Yp) / (\bar{Y}s / \bar{Y}p)$
- **Drought resistance index DI** = $Ys \times (Ys / Yp) / \bar{Y}s$

Where Ys and Yp represent yield under stress and none stress conditions respectively for each variety. While $\bar{Y}s$ and $\bar{Y}p$ represent yield mean in stress and non-stress conditions for all genotypes, respectively.

Statistical Analysis

All the data for the two growing seasons were analyzed using STATISTIX ANALYSIS SOFTWARE VERSION 8.0. Analysis of variance (ANOVA) for split-plot design was used to calculate means, standard errors, and significant differences between treatments. Probability of significance was used to see the significance and interaction between the treatments at $P \leq 0.05$ and $P \leq 0.01$ levels of significance. The standard error (SE) was used to compare means. Pearson's correlation coefficient was used to see the association between drought-tolerant indices and the Scattered graph was plotted to show the relationship between grain yield under non-stress and stress conditions.

RESULTS

Table (2) shows the effects of varying irrigation regimes, varieties, years, and their interactions on some yield-related parameters and yield of tropical wheat varieties. Results show a highly significant ($p<0.01$) effect on irrigation regimes of all the measured traits. 5 days irrigation regime was consistently higher than 15 days. Therefore, the values of these traits increased with irrigation increased.

The response of the varieties to the irrigation regimes varies significantly ($p<0.05$). The number of spikes per stand was almost significant ($P<0.05$) the same as all the varieties, however, TEEVEE'S has the highest mean value of 15.42 while the least value (12.83) comes from NORMAN. KAUZ-9 and TEVEE'S have the longest spike length (11.78 and 11.63 respectively). Followed by ATTILA-7 (10.85), REBWA-19 (10.57), and USHER (10.87). The shortest spike length (7.77) comes from SERI-82. The highest values for the number of grains per spike (56.08, 56.75, and 55.00) were recorded from KAUZ-9, USHER, and TEVEE'S respectively, while the least values (42.25, 43.92, and 41.33) come from NORMAN, GOUMRIA and SERI-82 respectively. From the result, values of thousand-grain weight for TEVEE'S and KAUZ-9 (45.10 and 44.36) respectively, were significantly ($P<0.05$) higher than the values of the rest of the varieties, the least values (37.36 and 38.24) were recorded from NORMAN and SERI-82 respectively. The result shows KAUZ-9 and TEVEE'S has the highest grain yield of (4.23)) followed by ATTILA-7 (3.53) and the least grain yield (2.63) comes from SERI-82. From the table, the interaction between irrigation and variety was not significant ($p<0.05$) under all the recorded traits.

Table 2: Effect of varying irrigation regimes on some yield-related parameters and yield of tropical wheat varieties grown in the savannah zone of Nigeria during the 2018/2019 and 2019/2020 dry farming season.

Treatments	Number of spikes per stand	Spike Length(cm)	Number of Grains per Spike	Thousand Grain Weight (g)	Grain Yield (GYD/T/ha)
Irrigations					
5 days	19.42[a]	11.14[a]	53.93[a]	47.17[a]	4.38[a]
15 days	8.70[b]	8.80[b]	45.03[b]	35.68[b]	2.36[b]
SE±	0.34	0.012	0.13	0.54	0.63
Varieties					
ATTILA-7	14.50[abc]	10.85[ab]	54.58[ab]	42.98[ab]	3.53[b]
ATTILA-50	13.83[abc]	9.23[de]	46.08[cd]	40.01[bcd]	3.13[bc]
GOUMRIA	14.33[abc]	8.64[de]	43.92[d]	42.23[ab]	3.00[bc]
IMAM	13.18[bc]	9.91[bc]	50.00[bc]	40.44[bcd]	3.53[b]
KAUZ-9	13.67[abc]	11.78[a]	56.08[a]	44.36[a]	4.23[a]
NORMAN	12.83[c]	8.38[de]	42.25[d]	37.36[cd]	2.88[bc]
REBWA-19	14.83[ab]	10.57[b]	48.83[c]	41.96[ab]	3.28[bc]
SERI-82	13.75[abc]	7.77[e]	41.33[d]	38.24[cd]	2.63[c]
TEVEE'S	15.42[a]	11.63[a]	55.00[a]	45.10[a]	4.23[a]
USHER	14.50[abc]	10.87[ab]	56.75[a]	41.53[abc]	3.25[bc]
SE±	1.01	0.53	2.45	1.80	0.34
Interaction					
Irrigation x Variety	NS	NS	NS	NS	NS

Means within each column followed by the same letter(s) are not significantly different at (P≤0.05) using SE. NS=Not Significant

Table 3A & B shows the values of drought indices in the tropical wheat varieties and that of the two planting seasons with their interactions, from the results, there is a significant difference among the varieties, SERI-82 has a significantly higher drought resistance index (DRI) and relative drought index (RDI) while geometric mean (GP) productivity and mean productivity (MP) were higher in KAUZ-9 and TEVEE'S (table 3A). Significant variation was observed in table 3B, the result grouped the varieties into two based on their significant differences under all the indices. Significance difference was observed among the two-planting season, DRI, RDI, stress tolerance index (STI), and yield stability index (YSI) were all significantly higher in 2018/2019 while GP, MP, stress susceptibility index (SSI), and stress tolerance (TOL) were higher in 2019/2020 planting season. The interaction between variety and planting season was highly significant under all the indices.

Table 3A: Drought tolerance indices in tropical wheat varieties grown in Bauchi state, during 2018/2019 and 2019/2020 dry farming season

Variety	Drought resistance index	Geometric mean productivity	Mean productivity	Relative drought index
ATTILA-7	0.51[b]	5.60[b]	3.53[b]	0.95[b]
ATTILA-50	0.68[ab]	4.46[bcde]	3.13[bc]	1.07[b]
GOUMRIA	0.61[ab]	4.22[cde]	3.00[cd]	1.14[ab]
IMAM	0.55[b]	5.65[b]	3.53[b]	1.02[b]
KAUZ-9	0.57[ab]	8.23[a]	4.23[a]	1.06[ab]
NORMAN	0.56[b]	3.66[de]	2.88[c]	0.98[b]
REBWA-19	0.45[b]	4.75[bcd]	3.28[bc]	0.92[b]
SERI-82	0.69[a]	3.30[e]	2.63[d]	1.28[a]
TEVEE'S	0.53[b]	8.27[a]	4.23[a]	0.78[b]
USHER	0.58[ab]	5.15[bc]	3.27[bc]	1.07[ab]
SE±	0.06	0.65	0.20	0.11
Season				
2018/2019	0.66[a]	4.78[b]	3.10[b]	1.22[a]
2019/2020	0.48[b]	5.88[a]	3.64[a]	0.89[b]
SE±	0.02	0.22	0.06	0.04
Interaction				
Variety x Season	**	**	**	**

Means within each column followed by the same letter(s) are not significantly different at (P≤0.05) using SE.
**** = significance at 1%**

Table 3B: Drought tolerance indices in tropical wheat varieties grown in Bauchi state, during 2018/2019 and 2019/2020 dry farming season

Variety	Stress susceptibility index	Stress tolerance index	Stress tolerance	Yield stability index
ATTILA-7	0.90[a]	0.51[b]	2.28[ab]	0.51[b]
ATTILA-50	0.78[ab]	0.58[ab]	1.92[b]	0.58[ab]
GOUMRIA	0.72[ab]	0.61[ab]	1.63[bc]	0.61[ab]
IMAM	0.84[a]	0.55[b]	2.20[ab]	0.55[b]
KAUZ-9	0.79[ab]	0.57[ab]	2.37[ab]	0.57[ab]
NORMAN	0.82[a]	0.56[b]	2.03[ab]	0.56[b]
REBWA-19	0.94[a]	0.50[b]	2.22[ab]	0.50[b]
SERI-82	0.58[b]	0.69[a]	1.00[c]	0.69[a]
TEVEE'S	0.88[a]	0.53[b]	2.77[a]	0.53[b]
USHER	0.79[ab]	0.56[ab]	1.77[bc]	0.58[ab]
SE±	0.11	0.06	0.37	0.06
Season				
2018/2019	0.64[b]	0.66[a]	1.35[b]	0.66[a]
2019/2020	0.97[a]	0.48[b]	2.67[a]	0.48[b]
SE±	0.04	0.02	0.15	0.02
Interaction				
Variety X Season	**	**	**	**

Means within each column followed by the same letter(s) are not significantly different at (P≤0.05) using SE.
**** = significance at 1%**

Figure 1 shows the yield of the varieties under non-stress and stress conditions, from the figure the grain yield was higher under the non-stress condition in all the ten varieties. From the figure, TEVEE'S has the highest grain yield under non-stress conditions followed by KAUZ-9, while SERI-82 has the least grain yield under non-stress conditions. However, under stress conditions, KAUZ-9 has a higher grain yield than TEVEE'S. The least yield under stress conditions was recorded in NORMAN.

Figure 2 shows the relationship between yield under nom-stress and stress conditions in all the varieties, the figures show a positive relationship between the grain yield under the two conditions. However, the relationship is not strong despite being positive. This shows that the yield in the varieties depends on the among of water applied and it varies among the varieties.

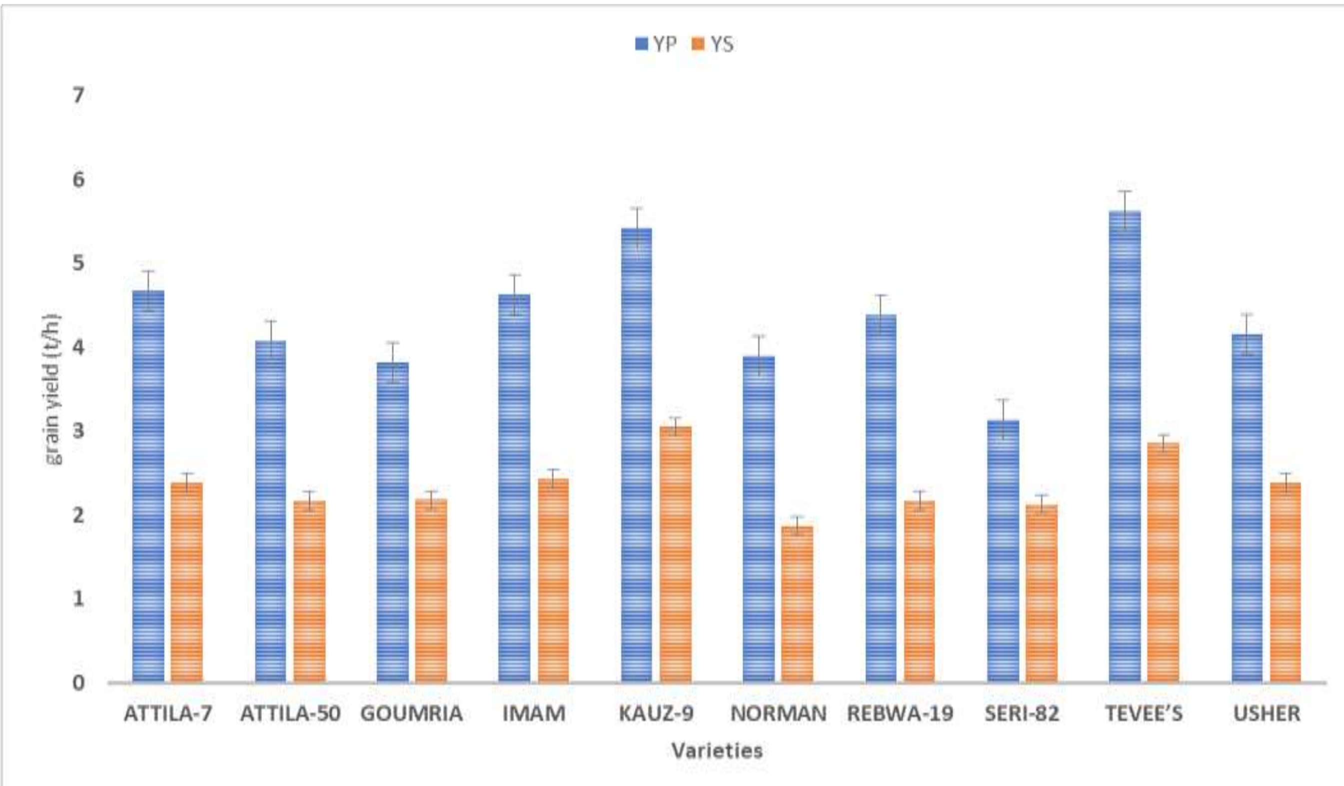

Figure 2: Grain yield in all the varieties under non-stress (YP) and stress (YS) conditions in tropical wheat varieties grown in Bauchi state, during 2018/2019 and 2019/2020 dry farming season

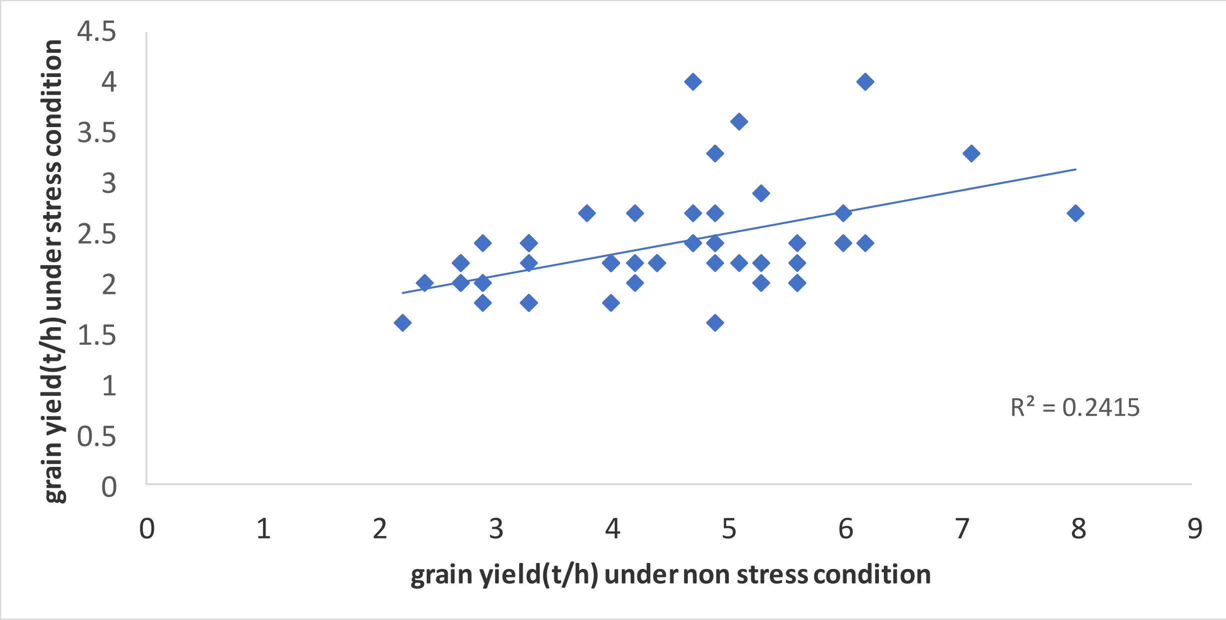

Figure 3: Relationship between grain yield of each variety grown under non-stress and water stress condition

Table 4 shows the correlation coefficients between the drought indices, from the table, positive significant correlations were observed between relative drought index, stress susceptibility index, stress tolerance index, and yield stability index with drought resistance index. There was also a negative correlation between geometric mean productivity, mean productivity, and stress tolerance with drought resistance index.

Table 4: Correlation coefficients between drought tolerance indices in tropical wheat varieties grown in Bauchi state, during the 2018/2019 and 2019/2020 dry farming season.

	Drought resistance index	Geometric mean productivity	Mean productivity	Relative drought index	Stress susceptibility index	Stress tolerance index	Stress tolerance
Geometric mean productivity	-0.2748*						
Mean productivity	-0.4774**	0.9687**					
Relative drought index	1.0000**	-0.2748*	-0.4774**				
Stress susceptibility index	1.0000**	0.2748*	-0.4774**	-1.0000**			
Stress tolerance index	1.0000**	0.2748*	-0.4774**	1.0000**	-1.0000**		
Stress tolerance	-0.9180**	0.5613**	0.7325**	-0.9180**	-0.9180**	-0.9180**	
Yield stability index	1.0000**	-0.2748*	-0.4774**	1.0000**	-1.0000**	1.0000**	-0.9180**

*= significant at 5%, **= significant at 1% significant level

DISCUSSION

Effect of water stress on yield and yield-related traits in tropical wheat varieties

From the results, we found out that water stress affects all the yield-related traits as well as the yield of the tropical wheat varieties. All the traits increased with reduced irrigation interval from 15-5 days interval. 5 days irrigation regime showed to have the highest value for these traits. This shows that moisture stress reduced the yield in tropical wheat (Khila *et al*. 2015; Blum 2016). The selection of appropriate variety has always been one of the essential components in cereal production (Luo, 2018). All cereals exhibit different ways of drought tolerance which is seen by their changes between availability and lack of water in the soil at all levels of growth, this change gives them the ability to enhance water status and this varies from variety to variety (Mihoub and Mokhtari, 2016; Chenchouni, 2017). KAUZ-9, TEVEE'S and ATTILA-7 varieties have a better result (table 2) compared to the rest of the varieties. Grain yield is significantly higher in KAUZ-9 and TEVEE'S, these two varieties have more stable photosynthetic capacity than others which gives them the ability to accumulate larger organic osmolytes in their system.

Drought tolerance indices in three tropical wheat varieties with their correlation

Drought tolerant indices provide a measure of stress resistance based on the minimization of yield loss under stress as compared to optimum conditions. It was used to characterize the relative stress tolerance of all genotypes (Fischer and Maurer, 1978). From table 3A & B the drought tolerance indices showed a significant difference in the varieties. Each index may be an indicator of different biological responses to water stress in the varieties because from the result it will be difficult to identify a single criterion that can be used for all the varieties in screening for drought tolerance, a similar observation was reported by (Sayed *et al*., 2013). GMP and MP are higher in KAUZ-9 and TEVEE'S compared to other varieties. These (GMP and MP) are used to identify wheat cultivars with higher yield stability under both stress and non-stress conditions (Sayed *et al*., 2013). STI, MP, and GMP have been reported to have a relative effect in selecting drought tolerance genotypes in many crops including wheat (Golabadi *et al.,* 2006). Wheat varieties with high values of MP and GMP with a correspondingly low value of TOL and SSI were found to have better yield performance under both water stress and non-stress condition (Sayed *et al*., 2013), this shows that all the tropical wheat varieties used in the study have the potential of stable yield performance under both stress and non-stress conditions, because their MP and GM values are all higher than their TOL and SSI values (Table 3A&B). The lower the value of TOL in variety, the more suitable the varieties are for drought conditions and can be used as a material in breeding for drought resistance, those with higher TOL values are more likely to be drought susceptible and are usually not suitable for drought conditions, similarly, varieties with lower SSI value of less than one is considered drought resistance than those with higher values (Pantuwan *et al*., 2002; Ouk *et al*., 2006; Sio-Se Mardeh *et al*., 2006). Based on this, all the ten tropical wheat varieties used in this study can be said to be drought resistant.

YSI is used to show how stable the yield of a particular variety is, under both drought and non-drought conditions, varieties with higher YSI are more stable than those with lower value, hence suitable for cultivation under water stress conditions. In this study all the tropical wheat varieties have less than one YSI value, since there is no value for comparison as in the case of SSI, we can conclude all the varieties have stable yield, and this can further be justified if we look at the positive correlation between YSI and STI (Table 4). Similar trends of results were reported in much previous work (Pantuwan *et al*., 2002; Ouk *et al*. 2006, Sio-Se Mardeh *et al*., 2006; Kumar *et al*., 2008; Raman *et al*. 2012).

CONCLUSION

In this studies the effect of irrigation watering regime on yield and yield-related traits of tropical wheat were observed, combined two years data analysis, shows a significant increase in all the observed traits with increased irrigation. We used several drought stress tolerance indices to see the water stress tolerance of ten different tropical wheat varieties. From the results, all the varieties show different levels of resistance to water stress based on the indices we used. However, KAUZ-9 and TEVEE'S proved to be more tolerant than others by showing little differences between their yield under normal and stress conditions.

RECOMMENDATIONS

From the results, KAUZ-9 and TEVEE'S are recommended for planting in a water deficit environment, even though all the varieties exhibit a certain level of tolerance. However, tolerance to water stress involved a complex network of activities involving a vast number of physiological, biochemical, morphological as well as molecular changes at different levels. Therefore, studying the relationship of several traits over a certain period of water stress regimes is recommended for a better understanding of the whole water stress tolerance in tropical wheat varieties.

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