Effect of Water Irrigation Shortage on Some Quantitative Characters at Different Rice Development Growth Stages

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Abstract: The field experiment were conducted during 2013 and 2014 rice growing seasons to study the effect of water shortage at the different growth stages viz., planting, tillering, panicle initiation, flowering and ripening on some growth and yield characters of thirteen rice genotypes grown in Sakha agricultural research station, Rice Research Section. The water stress conditions were withholding, flush irrigation every 10 days plus withholding 20 days at maximum tillering (T_1), flush irrigation every 10 days plus withholding 20 days at reproductive stage (T_2), flush irrigation every 10 days plus withholding 20 days at flowering stage (T_3), flush irrigation every 10 days (T_4) and normal irrigation (T_5). The results obtained indicated that water stress during vegetative stage reduced plant height, number of tillers/plant, chlorophyll content and induced leaf rolling in the susceptible rice genotypes. The reduction of grain yield, number of panicles /plant, 100-grain weight and high sterility percentage resulted from water stress at flowering and ripening stages. Water stress during vegetative, panicle initiation, flowering and through the season reduced grain yield by a bought 28%, 34%, 40% and 22% respectively, when compared with control are groups. The results indicated that the genotypes, GZ8710-3-2-1-1, GZ9730-1-1-1-1, GZ9730-1-1-3-2 and GZ9781-3-2-2-6 could be considered as drought tolerance rice genotypes and would be promoted to be new rice varieties.

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1. Introduction

Rice is the most important cereal crop in the world andit is the primary source of food and calories for about half of mankind (**Khush, 2005**).Sense the present food security inEgypt depends largely on the irrigated system, riceconsumes a large amount of water might reach 18-20% of the total water resources (**Abdallah, 2000**). Irrigation water is an important production factor in rice systems but is no longer available in unlimited rice-growing areas (**Bindraban, 2001**). In particular, rice is a very demanding crop in terms of water supply. It has been estimated that rice production consumes about 30% of the worldwide all freshwater (**Barker *et al*., 1999)**. Nowadays, about 75% of the global rice volume is produced in irrigated lowlands and is cultivated under submerged conditions created by the basin irrigation method (**Spanu *et al*., 2006**), this method requires a huge amount of water. **Nguyen, N. Vand Ferrero (2006)** addressed the water resource scarcity as one of the main limiting factors for the rice cultivation. Despite the world rice requirement is increasing, the competition from urban and industrial sectors, especially in Egypt. In Egypt water is becoming a main environmental issue for the society in next future. As regards to water cycle, climate changes will increase the occurrence and intensity of flooding and drought events. Therefore, the improvement of the efficiency of the water management systems in human activities is a crucial issue both for water saving and contamination reductions.

Irrigation shortage causes yield decrease and unfilled grain percentage in flowering stage. Significant reduction in tillers and panicles numbers as well as plant height and grain yield had been recorded when water stress imposed at tillering stage (**Farooq *et al*., 2009)**. On the other hand, moisture stress at late vegetative and reproductive stage results to reduction in number of panicles per plant, percentage of filled grains and 1000-grain weight. Also, the reduction in grain yield was noted when plants were exposed to water stress at panicle initiation stage, while the moisture stress at the milk ripe or dough ripe had significant effects on grain yield **De Datta *et al*., 1973). Nour *et al*. (1994)** reported that exposing rice plant to water stress for 36 days without flush irrigation during both tillering and panicle initiation significantly reduce plant height, number of tillers per plant, total dry matter, crop growth rate and grain yield. **Boonjung and Fukai (1996)** reported that drought stress during grains filling period results in acceleration of ripening time, causing reduction in growth period duration and filling grains. Performance of rice varieties under water stress varies greatly with some varieties being susceptible at vegetative stage and others at flowering and grain filling period **(Pantuwan *et al*., 2002). Bouman and Tuong (2001)** reported that different varieties may have different responses to the same drought stress timing and intensity. The objective of the study was to evaluate some rice genotypes under irrigation water shortage eat the different growth stages.

2. Materials and Methods

Two experiments were conducted at the Farm of the Rice Research and Training Center, Egypt, during 2013 and 2014 growing seasons to study the effect of irrigation water shortage on some quantitative characters of thirteen promising genotypes of rice in paddy fields. Split plot design with three replications was used, The irrigation treatments was subjected as the main plot viz. flush irrigation every 10 days plus withholding 20 days at maximum tillering (T_1), flush irrigation every 10 days plus withholding 20 days at reproductive stage (T_2), flush irrigation every 10 days plus withholding 20 days at flowering stage(T_3), flush irrigation every 10 days(T_4) and normal irrigation(T_5) and the rice genotypes as the subplot i.e., GZ 8452-4-1-1-1, GZ 8452-6-1-3-2, GZ 8710-3-2-1-1, GZ 8714-7-1-1-2, GZ 9724-11-2-1-2, GZ9730-1-1-1-1, GZ 9730-1-1-1-2, GZ 9730-1-1-3-2, GZ 9781-3-2-2-6, GZ 9792-13-1-1-2,GZ 9794-15-1-1-1, IET1444 and Giza178. The plot size of sup plot was $25m^2$ (5m x5m) each treatment was replicated three times. The amount of irrigation water applied was estimated by using water counter. Thirty day old seedlings of the rice genotypes were transplanted in three replications, each replicate comprised 10 rows of each genotype, the row was 5 m long and 20x20 cm apart was maintained between and within rows. Observations were recorded on 10 random plants for all studied traits. Days to heading (day), chlorophyll content (SPAD), leaf rolling, flag leaf area (cm^2), plant height (cm), panicle length (cm), number of tillers/plant, number of panicles/plant,100-grain weight (g), sterility percentage and grain yield/plant(g) were recorded. All cultural practices were applied as recommended and the data were analyzed by using Co-State software. Statistical analysis: The data collected were subjected to the analysis of variance (ANOVA) and treatments were compared using Duncan's New Multiple Range Test(DNMRT).

3. Results and Discussion

The data obtained during the two seasons were analyzed and the results could be discussed as follows. Genotypes mean squares were found to be highly significant for all vegetative characters studied, except leaf rolling at the two years, indicating overall differences among these genotypes on one hand and between the genotypes and years on the other hand, indicating that these genotypes behaved differently from year to year. Mean squares of treatments were found to be highly significant for all the vegetative traits at the two years, revealing that these genotypes affected severely by the shortage of irrigation water. Mean squares of the interaction between genotypes and treatments were significant for all the traits studied at the two years.

For days to heading, (Table 3), it is clear from the results obtained that the most desirable mean values towards earliness were observed by the genotypes, GZ 9792-13-1-1-2, GZ9730-1-1-1-1, GZ 9730-1-1-1-2, GZ 9730-1-1-3-2 and GZ 8710-3-2-1-1. The values ranged from 90.93 to 93.80 day at the two years. These differences among rice genotypes might be attributed to their genetic make-up. The opposite strategy was observed in other cultivars, which had a significant delay in maturity with drought. Heading delay is a common drought response observed in rice **(Lilley and Fukai, 1994),** which is expected to confer a benefit in those environments where stress is temporary, if development and flowering resume after the stress is relieved. With respect to irrigation treatments the results indicated that the most effective treatment for this treat was T_5, the delay in heading occurred due to increasing the intervals of irrigation water at the two years. Data in Figure (1) showed clearly that the genotype GZ9730-1-1-1-1 (87.00and 88.33) days to heading in the first and second season, respectively) was obtained irrigated with holding treatment (T_2). **Sikuku *et al.* (2010)** found that the varieties had significant difference in days to flowering where, the watering regimes affected the number of days taken by the plants to reach 50% flowering. The plants watered daily (control) took the least days to attain 50% flowering while plants watered after every six days which were the most stressed plants took the longest duration to attain 50% flowering.

With regard to chlorophyll content the results obtained (Table 3) indicated that the highest mean values were obtained from GZ 9794-15-1-1-1 (43.72 and 44.34) in 2013 and 2014 seasons, respectively, while, GZ 9724-11-2-1-2 rice genotype gave the lowest mean values (37.00 and 37.72) in the two seasons, respectively. The stable chlorophyll thylakoid complex under water stress condition under heat treatment has been reported in NH219 **(Panigrahy *et al.,* 2011).** The continuous flooding gave the desirable chlorophyll content values (45.49 and 45.91) in both seasons, respectively. The lowest values(39.09 and39.70)were obtained from water shortage at maximum tillering stage in both seasons, respectively. A major effect of drought is the reduction in photosynthesis, which arises by a decrease in leaf expansion, impaired photosynthetic machinery, premature leaf senescence and associated reduction in food production **(Wahid and Rasul, 2005).** The data in Figure (1) shows that the highest mean value of chlorophyll content were achieved from genotypes, GZ 9730-1-1-1-2, GZ 9730-

1-1-3-2 and GZ 9794-15-1-1-1 in the two seasons as compared with normal irrigation.

In this investigation, tolerance for water shortage can be assessed by visual scoring based on leaf rolling. Significant differences in visual score were found among the lines studied. The lines GZ 8452-6-1-3-2, GZ 8714-7-1-1-2, GZ 9724-11-2-1-2, GZ 8452-4-1-1-1 and IET1444 were the most tolerant to water stress while, the lines GZ 9794-15-1-1-1, IET1444 and GZ 9730-1-1-3-2 were the most intolerance. **Gaballah (2009)** mentioned that the drought every 12 days increased leaf rolling in rice genotypes**.** The desirable leaf rolling score was obtained from the interaction between the normal water irrigation treatment (T_5) and with genotypes IET1444 and Giza 178 in the two seasons. Leaf rolling greatly aids grasses, including rice, in minimizing transpiration water loss during water deficits **(O'TooLE *et al.*, (1979)**. A smaller degree of leaf rolling is taken as indicative of a greater degree of dehydration avoidance by the development of deep roots. **Jones (1979)** showed that the degree of leaf rolling at particular leaf water potential was dependent on the cultivar and, thus, care must be exercised when using leaf rolling as an index of the degree of water stress or dehydration avoidance. This implies that screening for drought resistance on the basis of leaf rolling will select for a range of drought resistance mechanisms.

With regard to flag leaf area (Table 4), the highest mean values were30.72 cm^2 and 31.73cm^2obtained from IET14444. On the other hand the rice genotypeGZ 8452-4-1-1-1 gave the lowest mean value(19.47 cm^2 and 20.49 $cm^{2)}$in both seasons, respectively. Reduced soil moisture levels produced lower leaf area; it might be due to inhibition of cell division of meristematic tissue under water starved condition. **Zubaer *et al.*(2007)** mentioned that the interaction effect of different moisture levels and rice genotype of leaf area per hill at all growth stages was significant. At booting stage, the highest leaf area was found at 100% FC in all the rice genotypes. The leaf area was reduced with the reduction of moisture levels but the degree reduction was higher in Basmoti (14.7 for 70%FC and 53.2% for 40%FC) cm. RD 2585 than in Binadhan 4 (5.6% for 70%FC and 43.4% for 40% FC). The mean value increased under continues flooding to be 29.63 cm^2 and 60.65cm^2 at the first and the second season, respectively. While the second treatment(T_2)decreased leaf area to 24.40cm^2 and 25.41 cm^2in the two seasons, respectively. Plant generally limits the number and area of leaves in response to drought stress just to cut down the water budget at the cost of yield loss (Schuppler et al., 1998).Similar findings were reported by **Gaballah (2009) and Abdallah *et al.* (2014).** The interaction between genotypes and irrigation treatments affected significantly the flag leaf area in both seasons. Data in figure (2) show that the superior values were 34.00cm^2 and 34.94cm^2 which obtained from rice genotype IET1444 under normal irrigation treatment in the first and second seasons, respectively. Otherwise, the declined values were detected from GZ8452-4-1-1-1 with water shortage at maximum tillering and the values were 15.87 cm^2 and 17.00 cm^2 in two seasons, respectively.

There was a significant difference in plant height between rice genotypes as shown in Table (4). GZ8714-7-1-1-2 gave the highest values 92.05 cm and (94.85 cm at the two seasons, respectively. While, the lowest mean values were detected in GZ8452-4-1-1-1 77.28 cm and 80.65 cm in both seasons, respectively. **Lafitte *et al.* (2006)** reported that significant differences were observed among the parental lines for plant height. Plant height values varied significantly by water shortagein the two seasons. The highest mean values were obtained fromT5 (94.07 cm and 97.17 cm) in both 2013 and 2014 seasons, respectively. **Lafitte *et al.* (2006)** indicated that the low land stress reduced height by only 4 cm (3%), ranging from a 43 cm reduction to 22 cm increase in height. Therefore, result in Figure (2) found significant differences among five irrigation treatments and genotypes interaction. The normal irrigation (T_5) gave the higher plant height values with rice genotype GZ8714-7-1-1-2 (107.60cm and 110.00 cm) in both growing seasons, respectively. While, the lowest values were (56.00cm and 59.50 cm) in two seasons, respectively, this obtained from water shortage at maximum tillering stage (T1) in conjunction with the rice genotype GZ8452-4-1-1-1. **Farooq *et al.* (2009)** mentioned that growth is accomplished through cell division, cell enlargement and differentiation and involves genetic, physiological, ecological and morphological events and their complex interaction.

Concerning panicle length, Table (4) the genotypes GZ 8710-3-2-1-1 and GZ 9781-3-2-2-6 gave the highest mean values under both normal and drought condition as compared with control the values were 22.0cm, 20.0 cm and 20.76 cm, 21.53cm at the two years, respectively. The lowest values obtained from the genotype GZ9730-1-1-3-2 (18.66, 19.44 cm) at the two seasons, respectively. Irrigation treatments affected significantly panicle length and the most effective irrigation treatment was (T_5), while, the declined values recorded from irrigation shortage at maximum tillering stage (T_1) at the two seasons, respectively. The interaction between genotypes and irrigation shortage treatments was highly significant for panicle length as show in figure (2). The desirable values were gained from normal irrigation treatment (T5) accompany with genotypes GZ9781-3-2-2-6 in the both seasons, respectively. **Sikuku *et al.* (2010)** recorded that there was no significant difference ($P \leq 0.05$) in panicle length among the varieties. Plants watered daily had longer panicles than plants watered after every 2, 4 and 6 days

For number of tillers/ plant, the results indicated that the irrigation treatments produced mild and sever water stress. Development of number of tillers/plant was more severely affected by the stress as shown in Table (5). These results demonstrate the more pronounced effect of water shortage on number of tillers at the two seasons; this may be due to reduced nutrient uptake under water stress which is a consequence of reduced demand for developing new tillers. The most desirable mean values were obtained from the genotypes GZ 8710-3-2-1-1, GZ9730-1-1-1-1, GZ 9792-13-1-1-2 and GZ 9730-1-1-3-2 which ranged from 19.00 to 20.34 tillers /plant at the two seasons. Water deficit during vegetative stage reduces tiller number. **Bouman and Toung (2001)** found that drought before or during tillering reduce the number of tillers. The T_5 was superior tillers in the first season, while the irrigated shortage T_1 was lowest tillers in second season. The data in Figure (3) illustrated the interaction between rice genotypes and irrigated shortage treatments for number of tiller/plant in both seasons. The highest mean values were found with the genotype Giza 178 with normal irrigation (24.30 and 25.43 tillers) in the first and second season, respectively). The lowest mean values attained by GZ9781-3-2-2-6 with irrigated shortage at maximum tillering stage.

With respect to number of panicles/plant (Table 5) tolerance for water stress is assessed by no. of panicles/plant which produced from number of tillers/plant, where under water stress most of the tillers do not bear panicles. The same genotypes i.e., GZ 8710-3-2-1-1, GZ9730-1-1-1-1, GZ 9792-13-1-1-2 and GZ 9730-1-1-3-2 were the most tolerant to water stress by producing high number of panicles/ plant, the values ranged from 16.24 – 18.87 panicles/ plant. Thus, plants in field experiments where irrigation is withheld for some time experience a progression of water deficit from mild to severe. This consideration is important in comparing the results of the present experiment with those obtained in the field. Irrigation shortage treatments insignificantly affected on number of panicles/plant, since the normal irrigation provided the larger values (17.37 and 18.65) in both growing seasons, respectively. While the lowest values obtained from irrigated shortage at maximum tillering stage were 12.32 and 13.56 in two seasons, respectively. Water stress at mid-tillering affects assimilates translocation from the most plant part to the panicles, via altering source-sink relationships. The reduction in leaf cell expansion would decrease sink strength for vegetative growth and lessen the competition with panicle growth for assimilates. **Davatgar *et al.* (2009)** showed that the number of panicles per hill under mild water stress at mid-tillering was the highest25.5 however, under severe water stress at mid-tillering, the number of panicles per hill decreased significantly to 16 panicles/hill. The rice genotypes and irrigated shortage periods interaction was highly significant for number of panicles/plant as shown in Figure (3). The uppermost number of panicles/plant value was realized from genotypes GZ 9730-1-1-1-2 with normal irrigation in both seasons. On the other hand, GZ9781-3-2-2-6 with irrigated shortage T_1 donated the lowest panicles/plant 9.53 and 10.87 in both seasons, respectively.

According to the results in (Table 5), 100-grain weight was affected significantly with drought stress imposed on rice genotypes studied. The genotypes GZ 9730-1-1-3-2, GZ 9792-13-1-1-2, GZ 8452-6-1-3-2 and GZ 8710-3-2-1-1 were recorded the highest 100-grain weight in both seasons which ranged from 2.54 – 2.68 g. These findings suggested that these lines could be considered as more resistance against water shortage conditions at the different growth stages than the others and the control. For respect to water treatments were found to be highly significant and the treatment (T1) gave the heaviest mean value of 100-grain weight while, the lightest one obtained from treatment (T_3). Different irrigation treatments and rice genotypes interacted significantly for producing 100-grain weight. The interaction between genotypes and irrigation shortage treatments was highly significant for 100-grain weight, therefore, the heaviest grains found by normal water irrigation (T_5) and with genotypes GZ9730-1-1-1-1. On the other hand, the lightest values obtained from Giza178 with irrigation shortage at flowering stage. **Kuixian *et al.* (2012)** reported that the water deficit during reproductive stage led to decreases 1000-grain weight in rice cultivars Zhenshan97B and IRAT109 compared to the well watered control.

For sterility percentage, Table (6) found to be highly significant differences between genotypes, therefore, the genotype GZ 8452-6-1-3-2 produced the highly sterility percentage values 28.03% and 26.49%. Otherwise, the lowest mean values obtained from GZ9730-1-1-1-2 were 14.06% and 12.85 % in two seasons, respectively. The drought stress every twelve days gave the highest mean value of sterility percentage **Gaballah (2009)**.The water irrigated shortage at flowering stage provided the higher sterility percentage 26.88% and 25.22% in both seasons, respectively, while the normal irrigated T_5 gave the lowest sterility percentage values 10.41% and 9.59% in first and second season, respectively. Data in Figure (4) illustrated the interaction among rice genotypes and irrigated shortage treatments affected significantly of sterility percentage, the lowest values were a gained from genotype GZ8452-6-1-3-2 under irrigated shortage at flowering stage 44.00% and 42.27% in the first and second season, respectively. The genotype GZ9730-1-1-1-2 combined with normal irrigation gave the lowest sterility percentage values 5.14% and 5.03% in two seasons, respectively.

With regard to grain yield, the rice genotypes were varied significantly in two seasons. The highest mean values obtained from GZ 9730-1-1-3-2 were 31.82 g and 32.42 g/plant in 2013 and 2014 seasons, respectively. Where, GZ 9792-13-1-1-2 rice genotype gave the lowest mean values 23.57 g and 23.97 g/plant in two seasons, respectively. It has long been recognized that some rice cultivars have more stable grain yields under drought than others **(Mackill *et al.*, 1996).** Consistent with this observation, the parental lines evaluated in this study showed tremendous yield variation in response to water level.

Table (1). Mean squares estimates of ordinary analysis for vegetative characters in 2013 and 2014 seasons.

S O V	df	Days to Heading		Chlorophyll Content (SPAD)		Leaf rolling		Flag leaf area (cm2)		Plant height (cm)		Panicle length(cm)		No. of tillers/plant	
		Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
Blocks	2	19.22**	18.4**	13.04**	29.08**	6.36**	15.38**	5.35**	6.28**	13.53ns	38.94**	19.00**	13.74**	84.25**	80.63**
Genotype	12	311.37**	302.67**	65.85**	65.90**	1.63ns	1.88ns	172.8**	172.58**	376.91**	369.81**	29.53**	29.68**	47.00**	46.5**
Error	24	1.68	2.45	1.57	1.66	0.85	1.13	0.77	0.80	5.45	6.17	1.95	1.89	4.75	4.80
Treat	4	130.92**	139.56**	315.04**	292.27**	27.92**	17.54**	349.75**	347.17**	2132.9**	2062.45**	269.61**	270.24**	257.90**	262.90**
Error b	8	7.78	6.15	3.75	2.99	1.27**	1.69	2.71	2.77	15.78**	18.84	5.94	5.57	9.25	9.78
T x V	48	7.21**	6.93**	20.79**	21.29**	1.40	1.51**	8.03**	8.08**	77.99	74.47**	2.91**	2.91**	2.69**	2.80**
Error	96	0.67	1.00	0.94	1.16	0.20	0.42	0.42	0.47	3.38	4.10	0.50	0.50	0.70	0.76
Total	194														

* Significant at 5% level of probability, ** highly significant at 1% level of probability and ns not significant probability

Table (2). Mean squares estimates of ordinary analysis for yield and its components characters in both 2013 and 2014 seasons.

S O V	Df	No. of panicles/plant		100-Grain weight (g)		Sterility percentage (%)		Grain yield/plant (g)	
		Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
Blocks	2	108.27 **	111.12 **	0.28 **	0.81 **	17.32 **	15.45 **	26.67 **	28.26 **
Genotypes	12	56.02 **	55.60 **	0.27 **	0.27 **	217.63 **	211.53 **	104.07 **	90.45 **
Error	24	4.88	4.85	0.01	0.01	1.27	1.37	1.90	3.91
Treat	4	137.46 **	139.41 **	0.35 ns	0.37 Ns	1,555.67 **	1,419.93 **	593.37 **	524.42 **
Error b	8	3.75	3.80	0.16	0.13	5.75	3.43	5.10	6.33
T x V	48	3.48 **	3.59 **	0.02 **	0.03 **	51.95 **	51.90 **	20.10 **	18.44 **
Error	96	0.51	0.53	0.01	0.01	0.88	0.97	0.93	3.21
Total	194								

* Significant at 5% level of probability, ** highly significant at 1% level of probability and ns not significant probability

Table (3). Effect of rice genotypes and irrigated shortage treatments as well as their interaction on the vegetative characters studied in 2013 and 2014 growing seasons.

Genotype	Days to heading		Chlorophyll content (SPAD)		Leaf rolling	
	2013	2014	2013	2014	2013	2014
GZ 8452-4-1-1-1	93.50 ± 2.13	95.00 ± 2.15	40.61 ± 4.10	41.22 ± 4.18	2.91 ± 0.92	2.44 ± 0.98
GZ 8452-6-1-3-2	94.47 ± 2.22	95.63 ± 2.54	40.26 ± 3.32	40.92 ± 3.36	2.78 ± 0.90	2.57 ± 0.90
GZ 8710-3-2-1-1	91.23 ± 1.61	92.66 ± 1.61	43.43 ± 2.43	44.10 ± 2.50	3.11 ± 1.15	3.08 ± 1.16
GZ 8714-7-1-1-2	97.20 ± 1.85	98.57 ± 2.04	40.48 ± 2.99	41.14 ± 3.02	2.89 ± 1.33	2.74 ± 1.43
GZ 9724-11-2-1-2	97.83 ± 2.87	99.30 ± 2.92	37.00 ± 2.38	37.72 ± 2.35	3.05 ± 1.00	2.70 ± 1.16
GZ9730-1-1-1-1	92.40 ± 4.64	93.60 ± 4.36	41.29 ± 3.45	41.96 ± 3.49	2.91 ± 0.99	2.53 ± 1.18
GZ 9730-1-1-1-2	91.57 ± 2.37	92.83 ± 2.52	42.58 ± 5.21	43.32 ± 5.27	3.07 ± 1.06	2.78 ± 1.25
GZ 9730-1-1-3-2	90.93 ± 3.05	92.30 ± 3.00	42.20 ± 4.10	42.89 ± 4.18	2.73 ± 0.77	2.67 ± 0.62
GZ 9781-3-2-2-6	98.57 ± 1.63	99.63 ± 1.88	38.03 ± 2.32	38.65 ± 2.34	2.51 ± 0.91	2.33 ± 1.11
GZ 9792-13-1-1-2	92.50 ± 1.75	93.80 ± 1.82	40.04 ± 5.85	40.71 ± 5.87	2.65 ± 0.85	2.67 ± 0.98
GZ 9794-15-1-1-1	94.93 ± 2.25	96.10 ± 2.62	43.73 ± 3.58	44.34 ± 3.58	3.78 ± 1.55	3.53 ± 1.41
IET1444	103.6 ± 1.80	104.77 ± 1.85	39.55 ± 3.49	39.77 ± 3.06	3.41 ± 1.67	3.34 ± 1.49
Giza178	104.8 ± 1.61	105.97 ± 1.74	43.55 ± 2.38	43.95 ± 1.98	3.01 ± 1.45	3.07 ± 1.39
Irrigation shortage						
T1	94.62 ± 4.49	95.88 ± 4.44	39.09 ± 3.34	39.70 ± 3.43	3.46 ± 1.12	3.18 ± 1.23
T2	93.67 ± 5.14	94.77 ± 4.98	39.50 ± 3.24	40.22 ± 3.24	3.54 ± 1.14	3.33 ± 1.20
T3	96.49 ± 4.29	97.77 ± 4.27	38.75 ± 3.59	39.44 ± 3.66	3.54 ± 1.00	3.15 ± 1.35
T4	95.15 ± 5.08	96.55 ± 5.22	42.06 ± 3.02	42.69 ± 3.06	2.82 ± 0.57	2.67 ± 0.64
T5	98.38 ± 4.70	99.71 ± 4.55	45.50 ± 2.87	45.91 ± 2.98	1.57 ± 0.26	1.69 ± 0.52

Table (4). Effect of rice genotypes and irrigation treatments as well as their interaction on flag leaf area, plant height and panicle length in 2013 and 2014 seasons.

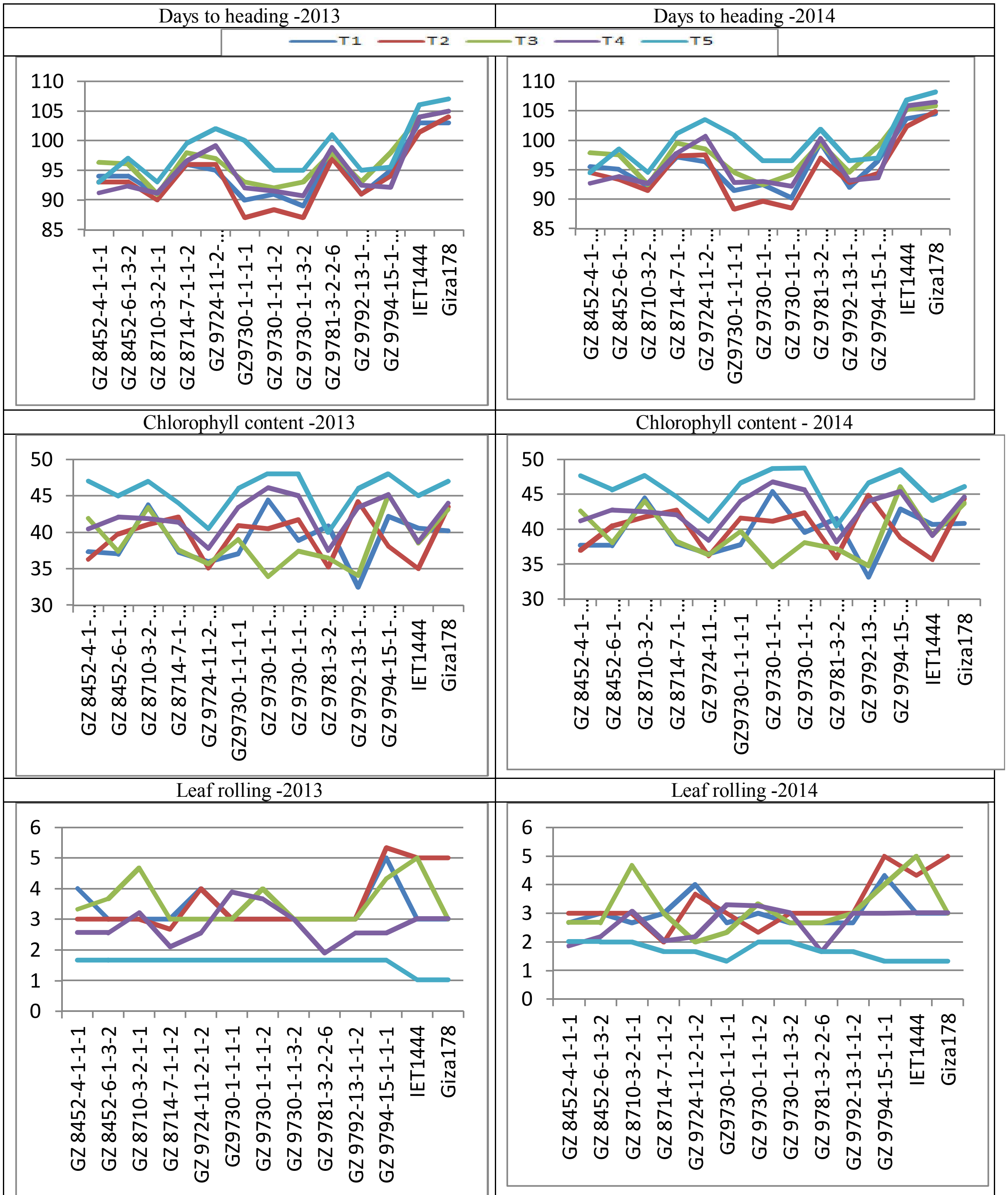
Genotype	Flag leaf area (cm2)		Plant height (cm)		Panicle length (cm)	
	2013	2014	2013	2014	2013	2014
GZ 8452-4-1-1-1	19.47 ± 3.46	20.49 ± 3.48	77.28 ± 13.93	80.66 ± 13.82	17.80 ± 2.33	18.59 ± 2.32
GZ 8452-6-1-3-2	21.81 ± 3.21	22.85 ± 3.21	80.52 ± 8.87	83.61 ± 9.15	20.53 ± 3.57	21.35 ± 3.54
GZ 8710-3-2-1-1	23.34 ± 3.54	24.37 ± 3.53	86.72 ± 9.13	89.87 ± 8.95	17.63 ± 2.31	18.43 ± 2.29
GZ 8714-7-1-1-2	23.37 ± 4.67	24.44 ± 4.68	92.05 ± 13.27	94.86 ± 12.95	20.12 ± 3.54	20.94 ± 3.51
GZ 9724-11-2-1-2	24.48 ± 3.03	25.49 ± 3.07	78.43 ± 8.22	81.86 ± 8.26	20.33 ± 2.62	21.16 ± 2.55
GZ9730-1-1-1-1	24.04 ± 2.36	25.09 ± 2.36	90.91 ± 6.78	94.05 ± 6.40	18.66 ± 2.90	19.44 ± 2.88
GZ 9730-1-1-1-2	28.07 ± 1.39	29.14 ± 1.38	90.15 ± 6.28	93.51 ± 6.36	18.07 ± 1.56	18.85 ± 1.55
GZ 9730-1-1-3-2	26.72 ± 1.85	27.77 ± 1.84	87.60 ± 5.20	90.95 ± 5.18	16.98 ± 1.79	17.78 ± 1.77
GZ 9781-3-2-2-6	28.06 ± 2.73	29.11 ± 2.68	88.75 ± 3.57	92.18 ± 3.48	20.76 ± 4.18	21.53 ± 4.20
GZ 9792-13-1-1-2	27.61 ± 3.45	28.65 ± 3.44	91.47 ± 7.24	94.87 ± 7.34	18.31 ± 2.33	19.14 ± 2.32
GZ 9794-15-1-1-1	29.35 ± 4.22	30.37 ± 4.22	89.58 ± 5.84	93.01 ± 6.00	18.83 ± 2.52	19.62 ± 2.51
IET1444	30.72 ± 3.84	31.74 ± 3.84	90.03 ± 6.68	93.27 ± 6.56	21.16 ± 2.29	21.96 ± 2.29
Giza178	29.58 ± 2.30	30.61 ± 2.31	88.27 ± 8.02	91.05 ± 7.46	20.44 ± 2.91	21.27 ± 2.94
Irrigation shortage						
T_1	21.76 ± 3.50	22.82 ± 3.50	77.69 ± 9.24	81.04 ± 9.29	16.34 ± 1.24	17.15 ± 1.20
T_2	24.40 ± 3.82	25.42 ± 3.85	82.31 ± 5.57	85.71 ± 5.62	17.29 ± 1.37	18.08 ± 1.35
T_3	26.23 ± 4.52	27.29 ± 4.52	86.48 ± 5.21	89.66 ± 5.51	18.68 ± 1.73	19.47 ± 1.71
T_4	27.45 ± 3.41	28.48 ± 3.40	94.73 ± 6.98	97.85 ± 6.80	20.97 ± 2.11	21.77 ± 2.09
T_5	29.63 ± 2.87	30.66 ± 2.87	94.08 ± 6.42	97.18 ± 6.05	22.73 ± 2.63	23.54 ± 2.62

Table (5). Effect of rice genotypes and irrigated treatments as well as their interaction on number of tillers/plant, number of panicles/plant and 100-grain weight in 2013 and 2014 seasons.

Genotype	No. of tillers/plant		No. of panicles/plant		100-Grain weight (g)	
	2013	2014	2013	2014	2013	2014
GZ 8452-4-1-1-1	16.20 ± 3.06	17.55 ± 3.12	13.55 ± 2.19	14.80 ± 2.29	2.50 ± 0.18	2.61 ± 0.20
GZ 8452-6-1-3-2	15.36 ± 2.78	16.79 ± 2.76	12.81 ± 2.12	14.10 ± 2.11	2.54 ± 0.26	2.64 ± 0.26
GZ 8710-3-2-1-1	17.92 ± 3.66	19.21 ± 3.79	16.24 ± 3.48	17.47 ± 3.51	2.55 ± 0.17	2.63 ± 0.18
GZ 8714-7-1-1-2	17.48 ± 2.08	18.95 ± 2.11	14.87 ± 1.80	16.17 ± 1.80	2.26 ± 0.17	2.36 ± 0.20
GZ 9724-11-2-1-2	14.96 ± 2.45	16.38 ± 2.61	12.62 ± 2.20	13.92 ± 2.20	2.32 ± 0.17	2.42 ± 0.19
GZ9730-1-1-1-1	18.03 ± 2.46	19.47 ± 2.48	15.42 ± 1.77	16.73 ± 1.76	2.50 ± 0.21	2.62 ± 0.25
GZ 9730-1-1-1-2	19.84 ± 2.89	21.19 ± 2.90	17.57 ± 3.09	18.87 ± 3.09	2.43 ± 0.19	2.52 ± 0.22
GZ 9730-1-1-3-2	19.00 ± 2.92	20.34 ± 3.09	17.05 ± 2.72	18.35 ± 2.72	2.58 ± 0.13	2.68 ± 0.18
GZ 9781-3-2-2-6	14.94 ± 3.14	16.33 ± 3.12	12.89 ± 2.83	14.21 ± 2.81	2.41 ± 0.10	2.53 ± 0.13
GZ 9792-13-1-1-2	19.08 ± 3.11	20.53 ± 3.09	16.87 ± 3.11	18.07 ± 3.27	2.57 ± 0.12	2.67 ± 0.16
GZ 9794-15-1-1-1	15.08 ± 2.27	16.52 ± 2.26	13.00 ± 2.04	14.30 ± 2.05	2.40 ± 0.16	2.49 ± 0.17
IET1444	15.62 ± 2.98	17.03 ± 3.00	14.55 ± 1.59	15.82 ± 1.57	2.24 ± 0.16	2.35 ± 0.18
Giza178	18.34 ± 3.97	19.80 ± 3.84	17.75 ± 2.60	19.07 ± 2.59	2.19 ± 0.11	2.28 ± 0.11
Irrigation shortage						
T_1	13.71 ± 2.53	15.02 ± 2.53	12.32 ± 2.39	13.56 ± 2.45	2.47 ± 0.23	2.56 ± 0.25
T_2	15.55 ± 2.26	17.04 ± 2.24	14.23 ± 2.41	15.53 ± 2.39	2.39 ± 0.20	2.51 ± 0.21
T_3	17.09 ± 2.56	18.49 ± 2.54	15.44 ± 2.74	16.74 ± 2.75	2.28 ± 0.17	2.37 ± 0.21
T_4	18.72 ± 2.16	20.13 ± 2.21	15.71 ± 2.38	17.01 ± 2.38	2.43 ± 0.18	2.53 ± 0.18
T_5	20.25 ± 2.59	21.67 ± 2.60	17.37 ± 2.88	18.65 ± 2.87	2.53 ± 0.18	2.64 ± 0.20

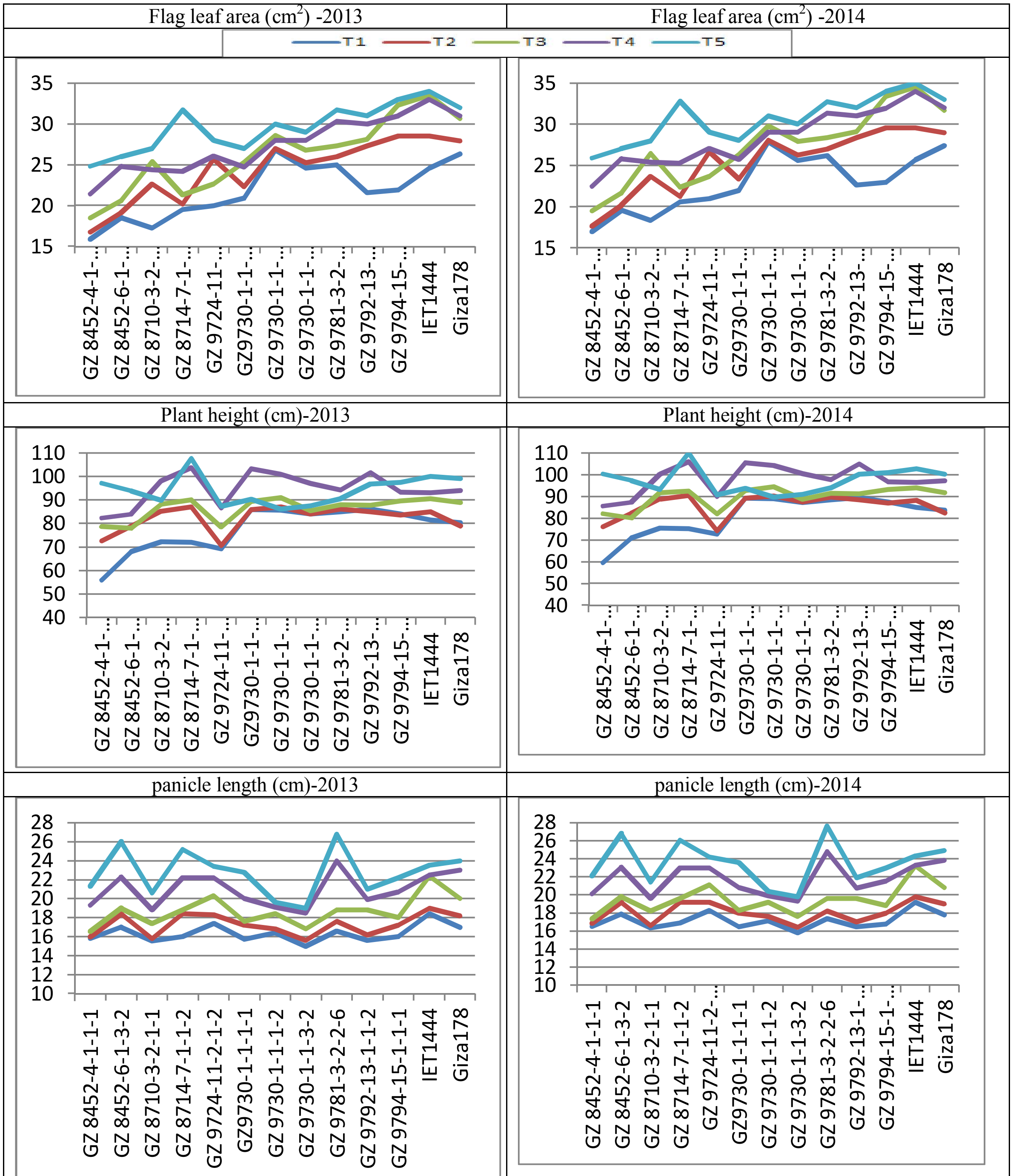
Table (6). Effect of rice genotypes and irrigated shortage treatments as well as their interaction on sterility percentage and grain yield /plant in 2013 and 2014 growing seasons.

Genotype	Sterility percentage (%)		Grain yield/plant (g)	
	2013	2014	2013	2014
GZ 8452-4-1-1-1	20.95 ± 7.58	19.45 ± 7.36	25.38 ± 5.92	25.93 ± 5.92
GZ 8452-6-1-3-2	28.03 ± 12.65	26.49 ± 12.45	26.35 ± 3.78	26.93 ± 3.78
GZ 8710-3-2-1-1	19.13 ± 8.18	17.67 ± 7.87	30.00 ± 4.75	30.10 ± 4.68
GZ 8714-7-1-1-2	16.04 ± 2.76	14.49 ± 2.60	27.93 ± 4.99	28.52 ± 5.00
GZ 9724-11-2-1-2	20.73 ± 7.12	19.07 ± 7.06	27.98 ± 2.34	28.59 ± 2.33
GZ9730-1-1-1-1	15.42 ± 5.71	14.08 ± 5.23	30.51 ± 2.00	31.84 ± 1.97
GZ 9730-1-1-1-2	14.06 ± 7.09	12.83 ± 6.84	29.63 ± 2.58	30.20 ± 2.61
GZ 9730-1-1-3-2	14.61 ± 6.94	13.11 ± 6.63	31.82 ± 2.95	32.42 ± 2.97
GZ 9781-3-2-2-6	16.53 ± 2.90	15.08 ± 2.93	30.58 ± 3.22	31.19 ± 3.25
GZ 9792-13-1-1-2	19.52 ± 9.80	18.06 ± 9.58	23.57 ± 6.52	23.97 ± 6.24
GZ 9794-15-1-1-1	16.89 ± 2.58	15.42 ± 2.39	27.40 ± 5.18	27.81 ± 5.08
IET1444	19.17 ± 6.15	17.80 ± 5.73	27.33 ± 2.60	28.54 ± 3.64
Giza178	14.60 ± 3.74	13.20 ± 3.53	23.92 ± 6.84	26.52 ± 6.28
T_1	16.97 ± 5.01	15.29 ± 4.97	25.82 ± 4.35	26.92 ± 4.15
T_2	21.50 ± 5.93	19.83 ± 5.95	23.97 ± 4.16	24.83 ± 4.00
T_3	26.88 ± 7.54	25.22 ± 7.50	21.61 ± 4.37	22.71 ± 4.79
T_4	14.88 ± 3.34	13.44 ± 3.31	31.89 ± 2.33	32.38 ± 2.30
T_5	10.41 ± 3.36	9.59 ± 3.15	35.85 ± 1.88	36.36 ± 1.96



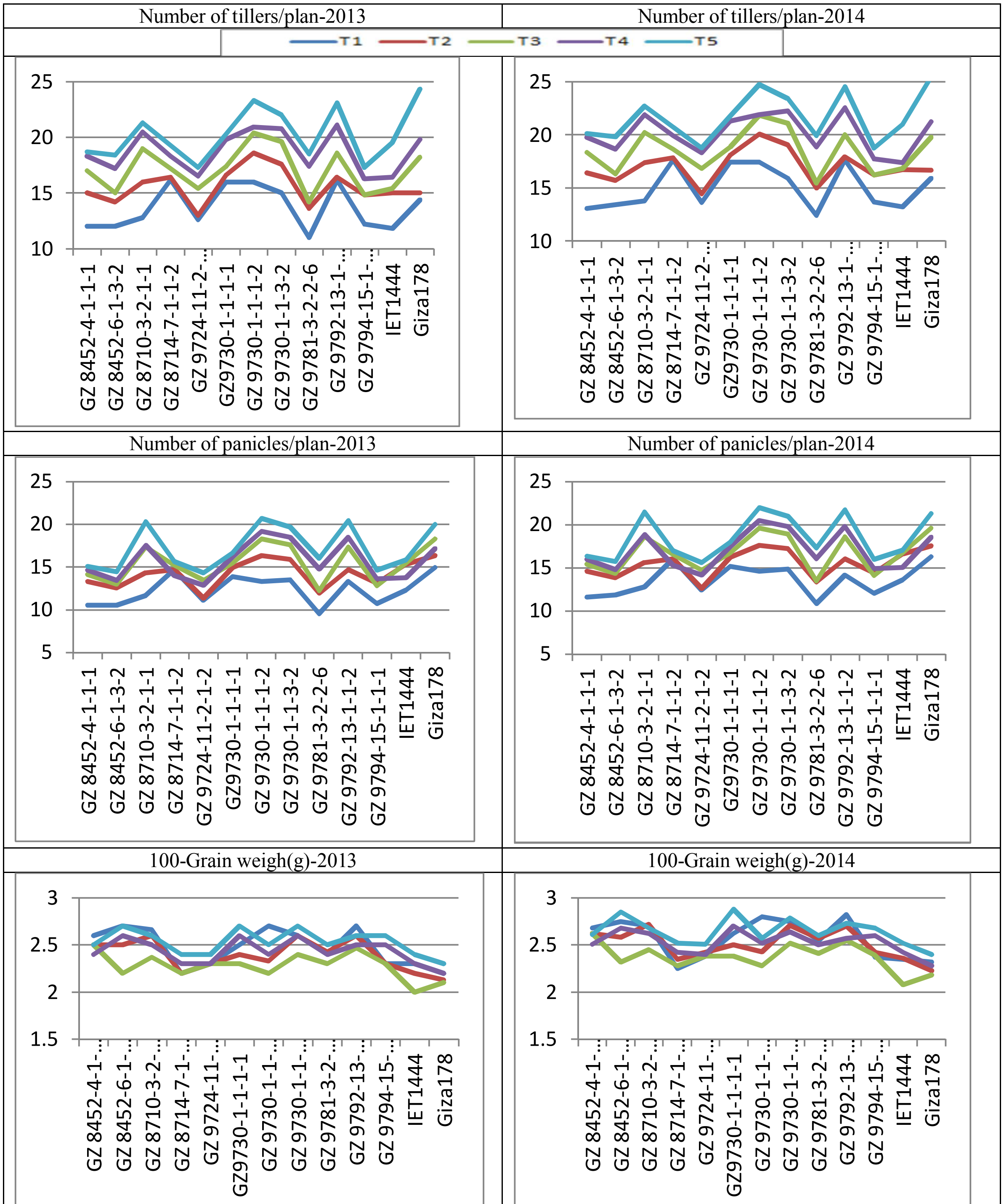
T_1: Flush irrigation every 10 days plus withholding for 20 days at maximum tillering stage.
T_2: Flush irrigation every 10 days plus withholding for 20 days at maximum reproductive stage.
T_3: Flush irrigation every 10 days plus withholding for 20 days at maximum flowering stage.
T_4: Flush irrigation every 10 days.
T_5: Normal Irrigation.

Figure (1). Interaction between genotypes and shortage irrigation treatments for days to heading, chlorophyll content and leaf rolling characters in 2013 and 2014 seasons.



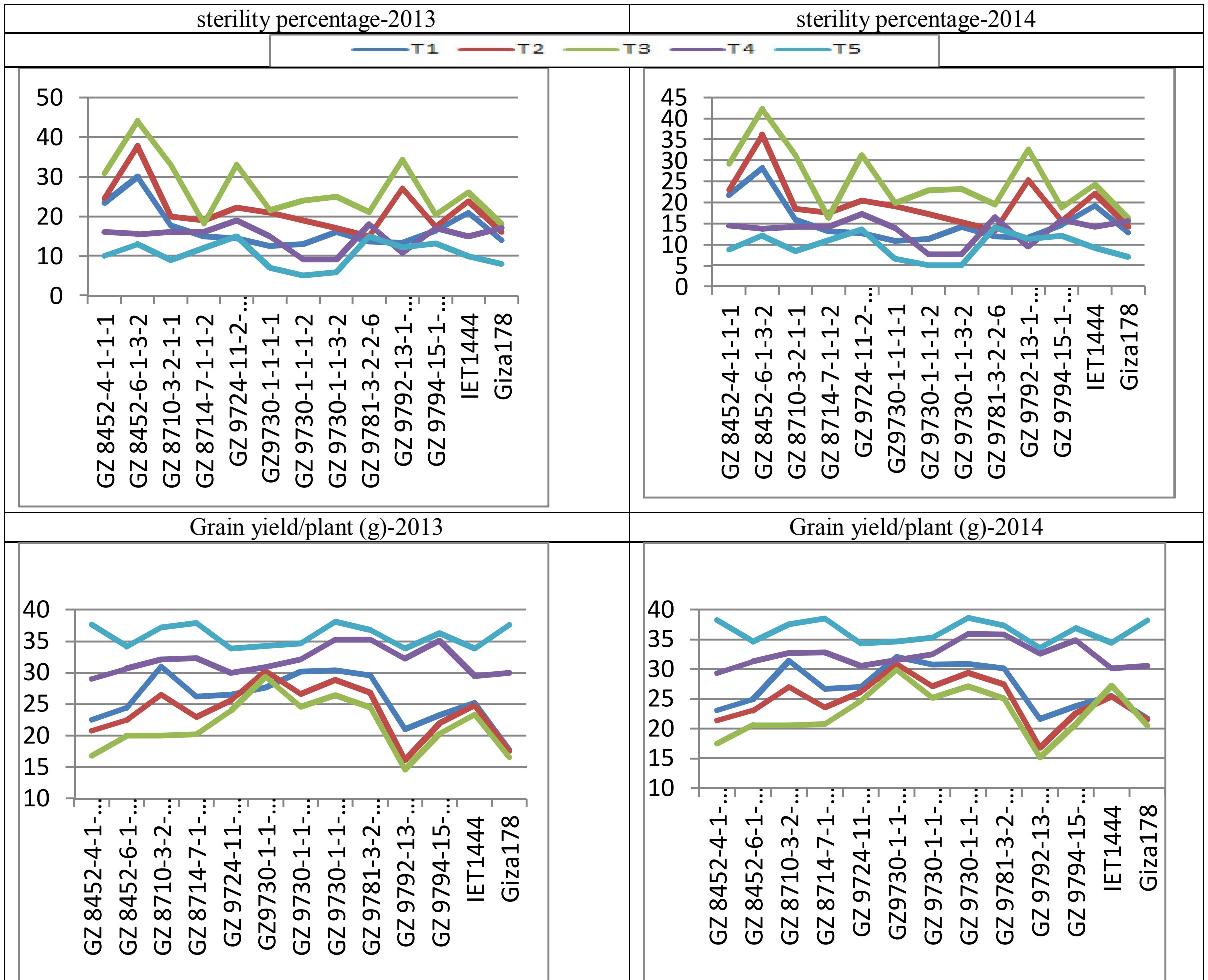
T_1: Flush irrigation every 10 days plus withholding for 20 days at maximum tillering stage.
T_2: Flush irrigation every 10 days plus withholding for 20 days at maximum reproductive stage.
T_3: Flush irrigation every 10 days plus withholding for 20 days at maximum flowering stage.
T_4: Flush irrigation every 10 days.
T_5: Normal Irrigation.

Figure (2). The interaction between genotypes and irrigation treatments for flag leaf area, plant height and panicle length characters in 2013 and 2014 growing seasons.



T_1: Flush irrigation every 10 days plus withholding for 20 days at maximum tillering stage.
T_2: Flush irrigation every 10 days plus withholding for 20 days at maximum reproductive stage.
T_3: Flush irrigation every 10 days plus withholding for 20 days at maximum flowering stage.
T_4: Flush irrigation every 10 days.
T_5: Normal Irrigation.

Figure (3). Showed that the interaction between genotypes and shortage irrigation treatments for number of tillers/plant, number of panicles/plant and 100-grain weight characters in 2013 and 2014 seasons.



T1: Flush irrigation every 10 days plus withholding for 20 days at maximum tillering stage.
T2: Flush irrigation every 10 days plus withholding for 20 days at maximum reproductive stage.
T3: Flush irrigation every 10 days plus withholding for 20 days at maximum flowering stage.
T4: Flush irrigation every 10 days.
T5: Normal Irrigation.

Figure (4). Showed that the interaction between genotypes and shortage irrigation treatments for sterility percentage and grain yield /plant characters in 2013 and 2014 growing seasons.

The absolute yields in our stress situations resulted from both the general adaptability of the tested lines to the local dry season environment as well as a wide range of stress response strategies. The irrigation shortage treatments showed highly significant differences for grain yield/plant. The normal irrigation gave the superior mean values 35.85 g and 36.36 g/plant in both growing seasons respectively. Whilst, the lowest mean values 21.61 g and 22.71 g/plant in two seasons respectively obtained from irrigated shortage at flowering stage. **Lafitte *et al.* (2006)** recorded that the lowland stress reduced grain yield to 75% and the upland stress treatment was severe and reduced grain yield to 48% of the upland control, where, Cultivars with greater yield potential tended to be proportionately more affected by stress than low potential or poorly adapted cultivars. The result in figure (4) showed that the highest grain yield/plant value was achieved from genotypes, GZ9730-1-1-3-2 combined with normal irrigation in the first and second seasons, respectively, while the lowest grain yield was obtained from genotype GZ9794-13-1-1-2 when accompanied with irrigation shortage at flowering stage. **Lafitte *et al.* (2007)** mentioned that the interaction between water level and cultivar was significant for grain yield and the water mid stress at reproductive stage reduced the grain yield by 53-92% and sever water stress reduced yield by 48-94%. The mid stress at grain filling reduced yield by 30-55%

compare with severe stress 60% at the same stage **(Basnayake *et al.* 2006).**

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