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THE ROLE OF ROOT SYSTEM TRAITS IN THE DROUGHT TOLERANCE OF RICE (*Oryza sativa* L.)

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ABSTRACT

A field and greenhouse experiments were conducted at Rice Research and Training Center, Sakha during 2008 and 2009 rice growing seasons to compare root system development of five rice varieties and lines ;viz., IET 1444, Giza 178, GZ 5121-5-2, GZ 1368-S-5-4 and Sakha 101, under drought stress, and to identify traits that confer drought tolerance. After fifteen days from sowing (15 DAS), drought stress was imposed in greenhouse for four days, followed by rewatering till harvesting. Root length density (RLD), root diameter (RD), leaf dry weight (LDW), stem dry weight (SDW) and root xylem vessels number (RXV) were measured at the end of the stress period during maximum tillering stage. Control plants were well watered throughout the study. GZ 5121-5-2 and GZ 1368-S-5-4 lines had thicker roots, higher root diameter, higher leaf and stem dry weights and higher root length density RLD (ratio of RLD in drought-stressed plants to that in control plants) than those under normal conditions. While, IET 1444 and Giza 178 cultivars had higher root diameter and leaf dry weight under normal conditions than under drought stress. Root xylem vessels number values were higher for all studied genotypes under drought stress than under normal conditions. The highest root xylem vessels were recorded for IET 1444, Giza 178 and GZ 5121-5-2 genotypes**.** The genotypes, Giza 178, GZ 5121-5-2 and GZ 1368-S-S-4, produced the highest grain yield under stress conditions compared to the others. Heritability estimates, in general, were higher for all studied traits. Related plant traits, such as root xylem vessels number, root length density, leaf and stem dry weights in IET1444, GZ1368-S-4-5 and GZ5121-5-2 genotypes were significantly more favorable for drought tolerance compared to Sakha 101 variety.

Keywords: Drought tolerance, Root system development, Rice varieties and lines

INTRODUCTION

Recovery from drought stress is an important fact of drought tolerance in plants. Koga (1997) stated that recovery from drought stress could be measured by comparing the growth of rice plants grown in water stressed and well watered conditions after a period of rewatering. The ability to recover from stress, speed of regrowth and vigor upon recovery of rice vary with the cultivars. However, less information is available on the drought stress recovery, compared with the plant behavior under drought stress and attention should be directed to the plants response to stress.

More studies on cultivar differences for root system development, during recovery from drought stress and the plant traits for drought tolerance must be conducted to understand the mechanism of drought recovery. Root system plays an important role under drought conditions. The nature and extent of root characteristics are considered to be major factors affecting plant response to water stress. Root length density (RLD) and root diameter (thickness) are used to characterize root system development of rice cultivars. The distribution of RLD in the root system is, also, an important indicator of the potential of water uptake (Sharp and Davies, 1985). Thick roots and number of roots in each tiller may, also, confer drought tolerance because branching is directly related to such characters.

Since a plant obtains its water and mineral requirements from its root and the availability of these resources often imposes a limit to plant productivity, it is difficult to overstate the importance of roots to plant productivity. Root development is, fundamentally, involved in the response to many plant stresses, in particular, drought and mineral deficiency. The possession of a deep and thick root system which allows access to water deep in the soil profile is crucially considered important in determining drought tolerance in upland rice and substantial genetic variation exists for this (Ekanayake *et al*., 1985b; Fukai and Cooper, 1995; O'Toole, 1982; Yoshida and Hasegawa, 1982). This trait may be less important in rainfed lowland rice, where hardpans may severely restrict root growth. Here, the ability to penetrate a hard layer is considered important and genetic variation in the ability to penetrate a layer of hard wax has been demonstrated (Yu *et al*., 1995). This trait may, also, be useful in upland rice, where high penetration resistance may limit rooting depth and where soils will harden as they dry. It is important to note two points here; 1) The penetration of roots through uniform hard layers, like wax, is probably achieved through the possession of large root diameter, which resists buckling (Cook *et al*.,1997), while when the impedance is due to a coarse textured sandy or stony horizon; it may be that thin roots would penetrate more easily. 2) The investment of carbon in a deep root system may have a yield implication because of lost carbon allocation to the shoot. It is vitally important to appreciate that root growth is, profoundly, influenced by the environment. Adverse conditions (chemical or physical) directly inhibit root growth (e.g. low water potential or high/low temperature). Biological factors in the root environment can also have a major influence on root distribution, but they are, generally, poorly understood. Particularly important is the presence of root feeding organisms such as nematodes, termites, mites and aphids that can severely reduce root proliferation or rooting depth and thereby affect drought resistance (Audebert *et al*., 2000). The shoot environment can, also, indirectly influence root growth either via carbon supply or signaling processes (e.g. light interception, water status and nutrient status).It has been suggested that plants respond to shifts in resource supply by allocating carbon to the organ involved in capturing the limited resource (Thornley, 1972; Dewar, 1993). When light is limiting, plants invest in shoot biomass. When nitrogen is limiting, they invest in root production. At the mechanistic level, theories implicating sucrose supply (Farrar, 1992), hormonal action (Jackson, 1993) or a combination of both (Van der Werf and Nagel, 1996), have been advanced to explain this phenomena. It seems clear that the root tip is an important component in the sensing and signaling of environmental cues to the whole plant (Aiken and Smucker, 1996). Responses to drought or temperature are probably complex due to a multiplicity of physical or biochemical processes directly affected. The present investigation aims to determine the differences in root system development between drought tolerant and drought intolerant varieties or lines under drought stress and after rewatering.

MATERIALS AND METHODS

The present investigation was carried out at the greenhouse and the farm of the Rice Research and Training Center at Sakha during 2008 and 2009 rice growing seasons, using five rice varieties and lines ;.i., Sakha 101(intolerant to drought stress), Giza 178, IET 1444 and the lines GZ 1368-S-5-4 and GZ 5121-5-2 (tolerant to drought). Seeds of each rice line and varieties were treated with fungicide and then pre-germinated in seed incubator at 30C for 24 h. Some seeds were sown directly in the nursery to be transplanted in the permanent field after 30 days from sowing for both normal (N) and drought (S) conditions. Drought stress was imposed by using flush irrigation every twelve days. Each pre-germinated seeds were directly sown in pots (25 cm in diameter and 60 cm in length). Each pot was cut into 10 cm depth segments which were sealed together with strong plastic tape, to prevent leakage of water. Pots were filled with clean fine sand and fertilized with NPK fertilizer. The experimental design used was randomized complete block design. The pots were arranged in the glasshouse in two rows with three replications. The seedlings were thinned to three per pot, two weeks after sowing. Pots were kept flooded fifteen days after sowing. Drought stress was imposed by irrigation every four days. The plants were left to depend on soil moisture supplied during the 4-day period of drought stress.

Results from previous experiments showed that the longest roots reached the 60cm depth below the pot soil surface at 65 days after sowing.

In the pots assigned for well watered control, water depth was maintained at 2-3cm depth above the soil surface. Root samples were taken in every 10cm layer depth at the end of the stress period. Sections were carefully cut at each layer to obtain the root density per 10cm layer and, at the same time, soil samples were collected from soil moisture determination. Root density was measured for every 10 cm layer depth, root diameter of five roots from the third node was measured at 2 cm from the tip of the root, in order to estimate the area for water absorption (Fuji, 1974).

Secondary roots (1 cm from the tip) from the test plants of each replication of all genotypes were sampled at 20, 30, 40, 50 and 60 days after sowing to determine the changes in xylem vessel number at the vegetative stage of growth. All sections were made by use of microtome for anatomical features. The microtome procedure was done following the technique of Johansen (1940).

The roots were immediately placed in a formalin solution after cutting. Root diameter was measured, using a microscope. Also, dry weights of green leaves and stems were measured at maximum tillering stage.

The combined analysis was calculated over the two years for both pots and field experiments to test the interaction of the different genetic components with the two years. The homogeny of error variance was tested as described by Bartlett (1937) and indicate that the error variance of the two seasons was not significant. The data was statistically analyzed followed by Burton (1952). Some genetic parameters were computed according to Johanson *et al*; 1955, Lush; 1940 and Burton, 1951.

RESULTS

Rice varieties differed in their root number (Table 1) in each 10 cm layer after four days water stress period among the studied genotypes. In the upper soil layers, 0-10 cm, there were no much differences in root density among the genotypes studied. From 10-40 cm, the vertical distribution of root differed significantly among the genotypes studied. IET 1444, Giza 178, GZ 5121-5-2 and GZ 1368-S-5-4 genotypes, had much deeper root distributions than Sakha 101, so they could effectively use more water stored at the deeper soil layers. Differences in the root density of deep and shallow rooted plants were found in the soil layers deeper than 20 cm. The root diameter of IET 1444, Giza 178 and GZ 5121-5-2 genotypes were less affected by drought stress than Sakha 101 (Table 2). The leaf and stem dry weights of IET 1444, Giza 178 and GZ 5121-5-2 genotypes were less affected by water stress and had more rapid recovery than Sakha 101 upon rewatering. IET 1444, Giza 178 and GZ 5121-5-2 genotypes, also, had significantly reduced leaf senescence as represented by lighter weight of dead leaves. These genotypes were found to survive better than the others under drought conditions.

Table 1: Vertical distribution of root density of the studied genotypes exposed to drought stress (greenhouse experiment)

Soil depth (cm)	Root density (%)				
	IET 1444	**Giza 178**	**GZ 5121-5-2**	**GZ 1368-S-S-4**	**Sakha 101**
0-10	13.30	11.00	15.50	16.00	18.00
10-20	2.56	3.10	4.30	5.00	7.50
20-30	0.6	0.7	0.9	0.8	0.4
30-40	-	-	0.2	0.3	-

Table 2: Root xylem vessels number, root diameter (mm), leaf dry weight (g) and stem dry weight (g) as affected by water stress of the studied genotypes (greenhouse experiment) as combined analysis of both seasons .

Genotype	Root xylem vessels number		Root diameter (mm)		Leaf dry weight (g)		Stem dry weight (g)	
	N	**S**	**N**	**S**	**N**	**S**	**N**	**S**
IET 1444	7.10	9.50	1.35	1.30	0.67	0.48	0.96	0.98
Giza 178	6.50	7.45	1.60	1.55	0.96	0.72	1.41	1.37
GZ 5121-5-2	5.30	7.90	1.58	1.60	0.81	0.85	1.10	1.22
GZ 1368-S-5-4	5.00	6.50	1.86	1.90	0.59	0.66	0.97	1.12
Sakha 101	4.00	4.10	1.00	1.11	1.42	0.45	1.58	0.87
LSD (5%)	0.55	0.40	0.19	0.23	0.65	0.38	0.02	0.15

N=Normal conditions. **S= Stress conditions.**

For number of panicles/plant (Table 3), Giza 178, GZ 5121-5-2 and GZ 1368-S-5-4 genotypes, possessed high number of panicles/plant under drought conditions, comparing with the check Sakha 101 variety. The mean values of number of panicles/plant ranged between 20.0 to 24.0 and from 18.0 to 19.0 panicles/plant under normal and drought conditions, respectively. This finding means that most of tillers beard panicles under drought conditions for these genotypes. For sterility %, the most desirable mean values towards this trait were observed by IET 1444, GZ 5121-5-2 and GZ 1368-S-5-4 genotypes, under drought conditions. These values ranged from 8.0 to 9.0% (Table 3). The same trend, also, was found for 100-grain weight. Giza 178 (11.42t/ha) and GZ 5121-5-2 (8.33 t/ha) genotypes gave the highest grain yield under both normal and drought conditions, respectively.

Table 3: Number of panicles/plant, 100-grain weight (g), sterility % and grain yield (t/ha.) as affected by water stress of the studied genotypes (field experiment) as combined analysis of both seasons.

Genotype	No. panicles/ plant		100-grain weight (g)		Sterility (%)		Grain yield (t/ha)	
	N	S	N	S	N	S	N	S
IET 1444	16.0	14.0	2.50	2.4	8.0	9.0	7.60	5.23
Giza 178	24.0	18.0	2.40	2.4	7.0	11.0	11.42	7.14
GZ 5121-5-2	20.0	19.0	2.55	2.5	7.5	8.0	10.71	8.33
GZ 1368-S-5-4	22.0	18.0	2.50	2.5	9.0	8.5	9.99	7.85
Sakha 101	22.0	11.0	2.50	2.3	8.0	17.0	10.71	4.28
LSD (5%)	1.7	1.5	0.10	0.1	1.2	2.5	0.05	0.03

N=Normal conditions. **S= Stress conditions.**

This study showed that, after drought stress period, the genotypes, Giza 178, IET 1444 ,GZ 1368-S-5-4 and GZ 5121-5-2, compared with Sakha 101, significantly differed in root system development as shown by relative root length density and root diameter. These genotypes had thicker roots than Sakha 101 variety and root thickness might be important in water uptake and translocation, as resistance to water flow might be less in thick roots. Total root length is strongly related to drought tolerance in rice under upland conditions (Ingram *et al*., 1994). Greater relative root length density in IET 1444, Giza 178, GZ 5121-5-2 and GZ 1368-S-5-4 genotypes, in 30-40 cm depth during drought stress might cause better water uptake. Thick roots may have greater capacity for water uptake from deeper soil drought resistance because root branching is related to root thickness (Fitter, 1991). Thick roots persist longer and produce more and larger root branches, thereby increase relative root length density and water uptake capacity (Ingram *et al*., 1994).

Rewatering resulted in a greater increase in relative root length density at deeper layers for IET 1444, Giza 178, GZ 1368-S-5-4 and GZ 5121-5-2 genotypes than Sakha 101 variety. Rewatering effects were more pronounced in the deeper roots below 20-60 cm than the shallow roots of 0-20 cm depth. After irrigation, IET 1444, Giza 178, GZ 1368-S-5-4 and GZ 5121-5-2 genotypes produced significantly heavier leaf and stem dry weights than Sakha 101.

The relationship between tillers and roots, also, were examined by tiller order (Table 4). Within the same variety, the primary tillers were larger in both number of roots per tiller and maximum root length than the secondary tillers, which, in turn, were larger than the tertiary tillers, in most cases.

Table 4: Number of roots found on tillers, maximum root length and root dry weight of different orders at flowering stage (greenhouse experiment) as combined analysis of both seasons.

Tiller order	Shoot (no.)	Total roots (no.)	Roots in each tiller (no.)	Maximum root length(cm)	Root dry weight(g)
Sakha 101					
Main shoot	1	71.0	71.0	38.0	3.0
Primary tiller	9	285.0	28.5	33.0	
Secondary tiller	20	320.0	12.8	28.0	
Tertiary tiller	8	125.0	15.6	18.0	
LSD 0.05	3.50	8.5	5.3	3.6	
Total	38	801	127.90		
GZ 1368-S-5-4					
Main shoot	1	58.0	58.0	48.0	24.0
Primary tiller	7	175.0	25.0	43.0	
Secondary tiller	18	196.0	10.88	43.0	
Tertiary tiller	7	65.0	9.28	30.0	
LSD 0.05	2.80	6.70	3.4	2.5	
Total	33	494	103.16		
GZ 5121-5-2					
Main shoot	1	62.0	62.0	45.0	21.0
Primary tiller	6	191.0	31.81	40.0	
Secondary tiller	15	210.0	14.0	40.0	
Tertiary tiller	6	52.0	8.66	25.0	
LSD 0.05	3.20	7.20	4.1	3.5	
Total	28	515	116.47		
Giza 178					
Main shoot	1	55.0	55.0	41.0	20.0
Primary tiller	8	148.0	18.5	37.0	
Secondary tiller	13	166.0	12.76	36.0	
Tertiary tiller	4	45.0	11.25	18.0	
LSD 0.05	3.30	5.5	2.70	3.0	
Total	26	414	97.51		
IET 1444					
Main shoot	1	60.0	60.0	42.0	19.0
Primary tiller	6	150.0	25.0	35.0	
Secondary tiller	10	170.0	17.00	33.0	
Tertiary tiller	5	48.0	9.60	12.0	
LSD 0.05	2.50	6.8	6.60	4.8	
Total	22	428	111.60		

IET 1444, Giza 178, GZ 5121-5-2 and GZ 1368-S-5-4 genotypes had the deepest root system while, the variety, Sakha 101 had the sallowest one. Maximum root length of the main shoot ranged from 38.0 cm, for Sakha 101, to 48.0 cm for GZ 5121-5-2. Varietal differences were much greater in number of roots in each tiller than in maximum root length.

The studied genotypes had from 3.50 to 6.00 xylem vessels at twenty days after sowing and the number differentially increased to a range of 4.10 to 9.50 at sixty days after sowing (Table 5). The results showed that IET 1444, GZ 5121-5-2 and Giza 178 genotypes, produced the highest number of xylem vessels, while, the variety, Sakha 101, produced the lowest number and GZ 1368-S-5-4 was intermediate. The genotypes, IET 1444, Giza 178 and GZ 5121-5-2, significantly produced higher number of root xylem vessels than the other genotypes in all sampling dates. In general, the growth pattern of root xylem vessels of the four genotypes IET 1444, GZ 5121-5-2, Giza 178 and GZ 1368-S-5-4, were similar. While, there was a continuous increase in root xylem vessels from one sampling date to another for IET 1444, Giza 178 and GZ 5121-5-2. Also, from results obtained there are a rapid increase in root xylem vessels from 20 DAS to 60 DAS for the three genotypes, IET 1444, Giza 178 and GZ 5121-5-2. The same results were found by Abd Allah (2004). This result implies that the numbers of xylem vessels were closely related to the capacity of the plant to transport water and nutrients absorbed from the soil.

Table 5: Mean root xylem vessel number of the studied rice genotypes measured at five different times of growth (greenhouse experiment).

Genotype	Number of days after sowing				
	20	30	40	50	60
IET 1444	5.18	6.80	8.70	8.30	9.50
Giza 178	5.10	5.56	7.04	7.53	7.45
GZ 5121-5-2	6.00	6.70	8.30	7.50	7.90
GZ 1368-S-5-4	4.70	5.10	6.54	7.00	6.50
Sakha 101	3.50	4.00	4.30	4.70	4.10
LSD (5%)	0.45	0.33	0.38	0.47	0.40

Table 6. Range, mean and genetic parameters for different traits in some rice genotypes under both normal and drought conditions.

Character	Range		Mean		Phenotypic variance (%)		Genotypic Variance (%)		Heritability (%)	
	N	S	N	S	N	S	N	S	N	S
R.X.V.	4.00- 7.10	4.10-9.50	5.60	7.90	22.00	28.50	17.00	22.30	77.00	88.00
RD	1.12-1.82	1.13-1.86	1.47	1.47	0.07	0.08	0.07	0.08	93.63	97.62
LDW (g)	0.58-1.41	0.41-0.82	0.86	0.61	0.11	0.03	0.11	0.03	98.23	97.00
SDW (g)	0.91-1.54	0.85-1.35	1.20	1.09	0.07	0.04	0.06	0.04	97.03	95.86
GY/plant (g)	32.16-48.02	18.10-35.05	42.49	27.74	37.50	53.25	33.35	50.80	0.89	0.94

N=Normal condition, S= Stress condition, R.X.V. = root xylem vessel number, RD= Root diameter, LDW= Leaf dry weight, SDW= Stem dry weight and GY= Grain yield /plant.

In general, the phenotypic variance (P.V.) was high for root xylem vessel number and grain yield / plant under both normal and stress conditions. The values ranged from 28.50 to 53.25 (for stress conditions) and from 22.00 to 37.50 (for normal conditions).

Genotypic variance (G.V.) showed the same trend. Heritability estimates, in general were higher for all studied traits. Consequently, selection for these traits could be more effective in most of the studied traits. The same results were found by Ram (1994) and Fukai *et al*. (1999) by using other genotypes.

DISCUSSION

This study showed that after the five days drought stress period, IET 1444, GZ 5121-5-2, Giza 178, GZ 1368-S-5-4 and Sakha 101 significantly differed in root system development, as shown by root length density, root xylem vessels number and root diameter. Maximum root length (primary, secondary and tertiary tillers) and root dry weight were higher in GZ 1368-S-5-4, GZ 5121-5-2, Giza 178 and IET 1444 than in Sakha 101(Table 3). Total root length is strongly related to drought tolerance in rice under drought condition (Ingram *et al*., 1994). Greater root length density (RLD) in GZ 5121-5-2 and GZ 1368-S-5-4 (in 20-40 cm depth) during drought stress might cause better water uptake, as indicated by their higher grain yield than Sakha 101. Begum (1985) observed that upland varieties had higher number of root xylem vessels than those of lowland varieties. Haque (1985) reported that the highest xylem vessel number was observed in drought tolerant genotypes .Thick roots might have greater capacity for water uptake from deeper soil layers (Yambao *et al*., 1992). Thick roots are also hypothesized to confer drought tolerance because root branching is related to root thickness (Fitter, 1991). Thick roots persist longer and produce more and larger roots branch, thereby increase root length density and water uptake capacity (Ingram *et al*., 1994). Drought stressed GZ 5121-5-2, GZ 1368-S-5-4 and IET1444 significantly produced heavier leaf and stem dry weights than Sakha 101. The greater ability to extract water and the greater dehydration tolerance during water deficit increased the growth rate during recovery (Lilly and Fukai, 1994).The genotypes, GZ 5121-5-2, GZ 1368-S-5-4 and IET1444, had plants that were able to keep water potential high by absorbing water and conducting it to the shoot, due to they posses high values of desirable root traits that associated with drought avoidance mechanism.

Such marked differences in number of roots might be accounted for, in part, by differences in assimilate supply to root growth. Competition for assimilate supply would occur between a growing tiller and roots of the mother shoot when active tillering proceeds. Drought tolerant rice genotypes had fewer numbers of roots, but a higher proportion of the roots were distributed in the lower soil layers below 20 cm.

As consequence, assimilate supply to roots of the mother shoot would be reduced, resulting in restricted root growth. Also, even after the tiller has become sustaining, an increased number of tillers/plant would increase mutual shading within the plant. Shading reduces root growth more than shoot growth.

For these reasons, a highly-tillered plant tends to have a short root system. The partition of assimilate between shoot and root accounts for the differences between Sakha 101 and the other genotypes. A plant with few and early tillers tends to have a deep root system. Low tillering capacity appears to be one desirable characteristic when rice plant has to depend on soil moisture retained in the deep soil layers during drought stress.

On the other hand, the low tillering capacity appears to be a major factor for limiting the yield potential for drought varieties under the most favorable cultural conditions. This is based on the analysis that the inherent low yielding capacity of traditional drought varieties is due to limited panicle numbers per unit area (Abd Allah, 2004). The previous reports indicted that yielding ability of the tall dry land varieties might be increased by modifying plant height to moderately tall or short stature. The tall and low tillering varieties, usually, bear large panicles. It may be possible to look for varieties that bear even larger panicles on the main shoot and few primary or secondary tillers.

Furthermore, when panicle numbers/unit area is limiting, yield can be increased by increasing seeding density.

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دور صفات النظام الجذرى فى تحمل الجفاف فى الأرز

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تم اقامة تجربتين أحداهما بالحقل والأخرى بالصوبة فى مركز البحوث والتدريب فى الأرز بسخا-كفرالشيخ-مصر خلال الموسمين الزراعيين ٢٠٠٨ و٢٠٠٩ . تهدف الدراسة الى مقارنة نمو النظام الجذرى فى خمسة تراكيب وراثية من الأرز وهى: IET 1444، جيزة ١٧٨، GZ 5121-5-2، GZ 1368-S-5-4، سخا ١٠١تحت ظروف الجفاف وأيضا لتحديد الصفات الهامة بالنبات والتى تجعله يتحمل الجفاف.

تم تنفيذ معاملات الجفاف بعد الشتل بخمسة عشر يوما حيث كان الرى كل أثنى عشر يوما بالنسبة للحقل وكل أربعة أيام بالنسبة للصوبة. تم قياس صفات كثافة طول الجذر، مساحة الجذر، الوزن الجاف للورقة ، الوزن الجاف للساق، وعدد الأوعية الخشبية وذلك فى مرحلة أقصى تفريع (٦٥ يوم بعد الزراعة).

ويمكن تلخيص أهم النتائج المتحصل عليها كما يلى:

١- أوضحت النتائج أن السلالات (GZ 5121-5-2, GZ 1368-S-5-4) تحتوى على قيم عالية لصفات سمك الجذر ، ، مساحة الجذر، الوزن الجاف للورقة، الوزن الجاف للساق وكثافة طول الجذر تحت ظروف الجفاف مقارنة بالظروف العادية. بينما أعطت الأصناف IET 1444و جيزة ١٧٨ قيم عالية لصفة مساحة الجذر ووزن الورقة الجاف تحت الظروف العادية مقارنة بظروف الجفاف. وكانت قيم عدد الأوعية الخشبية عالية لكل التراكيب الوراثية المختبرة تحت ظروف الجفاف مقارنة بالظروف العادية.

٢- أظهرت النتائج أن السلالات GZ 5121-5-2, GZ 1368-S-5-4 أعلى قيم لصفة عدد الأوعية الخشبية ، وأعطت التراكيب الوراثية جيزة ١٧٨، GZ 5121-5-2, GZ 1368-S-5-4 أعطت أعلى قيم لمحصول الحبوب تحت ظروف الجفاف مقارنة بالأصناف الأخرى.

٣- أشارت النتائج الى أن قيم درجة التوريث للصفات المدروسة عالية بكل التراكيب التى تم أختبارها.

توصى هذه الدراسة بأن صفات النبات مثل عدد الأوعية الخشبية ، كثافة طول الجذر، الوزن الجاف للورقة ، والوزن الجاف للساق فى التراكيب الوراثية المتحملة للجفاف IET 1444, GZ 5121-5-2, GZ 1368-S-5-4 كانت من أهم العوامل التى جعلتها متحملة لظروف الجفاف مقارنة بالصنف الحساس وهو سخا ١٠١.

قام بتحكيم البحث

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