Assessment of drought tolerance in segregating population in bread wheat

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Abstract:

Wheat improvement for drought tolerance requires reliable assessment of drought tolerance variability among segregating populations. The breeding materials used in this study were the F_2, F_3 and F_4-generations of the cross between Sids 4 x Kasyon/glennson-81 (*Triticum aestivum* L.) at Faculty of Agriculture, Sohag University, Egypt, to estimate the observed and the expected responses to selection and other genetic parameters under normal and drought stress conditions. Mean squares obtained from the analysis of variance revealed highly significant differences among F_3 and F_4 generations for all the traits studied under two environments. The observed direct response to selection for days to heading for early selected families was negative and highly significant compared with bulk and the check cultivar (Sahel 1) in F_4 with values of -4.84 and -13.28 % under drought conditions. The expected response to selection was 3.34% under drought conditions. Meanwhile, the observed direct response to selection for grain yield/plant of the highest yielding families was positive and highly significant compared with bulk, better parent and the check in F_4 with values of 15.52, 8.23 and 11.46 % under water stress conditions. On the other hand, the expected response to selection was 10.19% under drought conditions. High broad sense heritability values for days to heading of the early families were obtained under normal and drought stress in F_3 and F_4 generations, while narrow sense heritability was 36.24 and 44.45 in F_4 generation under normal and drought stress, respectively. The broad sense heritability for grain yield/plant of the highest yielding families was high under normal and water stress in F_3 and F_4 generation, while, the narrow sense heritability was 49.10 and 57.01in F_4 generation under the two studied conditions, respectively. These results showed that the pedigree method of selection was effective to produce new lines tolerant to drought stress with high grain yield. Drought susceptibility index showed that the six families, i.e., no. 1, 17, 18, 20, 26 and 32 produced relatively high grain yield under drought stress environments due to high yield potential, rather than having low susceptibility to stress environments. These genotypes could be used as source of drought tolerance/or factors contributing to general adaptation.

Introduction

Wheat (*Triticum aestivum* L.) is the world most cultivated food crop known as the king of all cereal crops as its cultivation is easier, ecologically suitable and contain high amount of nutrients. Wheat is cultivated over an area of 3.1 million feddan with a production of 8.7 million ton in Egypt.

Emphasis is given to explore the ways and means to increase the production of wheat to meet the increasing demand of food grains for the growing population. Currently it is not possible to increase the area under wheat due to other competing crops and restricted supply of irrigation water. Use of varieties with better yield potential and wide range of adaptability is of prime importance for increasing wheat production. Thus development of high yielding wheat cultivars has always been a major objective of wheat breeding programs throughout the world. Extensive testing of wheat genotypes under varying environments has been practiced for screening relatively stable cultivars (Aggarwal & Sinha, 1984).

Therefore, in Egypt, early maturity is one of the important objectives in spring wheat breeding programs. Earliness in wheat has several advantages, for instance, early maturing cultivars are highly needed to fit in new crop intensive rotation as planting cotton after wheat and planting wheat after harvesting short duration vegetable crops, etc. Also, wheat cultivars that can be harvested early provide farmers with more time to grow

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another crop such as Berseem. Moreover, earliness ensures timely crop harvest and may also protect wheat from biotic and abiotic stresses such as disease, heat and drought (Poehlman and Sleper 1995). Early heading and maturity cultivars in wheat are advantageous in areas where temperature rises greatly during the grain filling phase (or late sowing) as in Upper Egypt and they also provide more options for farmer to adopt diverse crop patterns, and potential drought escape mechanism (Mahar et al. 2003) .

The efficiency of a breeding program for drought tolerance depends largely on the efficiency of selection criteria and the selection method used to achieve the genetic improvement through selection. In addition to the complexity of the drought itself (Passioura, 1996, 2007), plant response to drought is complex and plants adopt different mechanisms when they encounter drought (Levitt 1980, Jones et al. 1981, Jones 2004). The most important mechanism is drought escape by rapid development that allows plants to finish their cycle before severe drought stress occur, so the selection for earliness is very beneficial to drought tolerance.

Heritability of days to heading and grain yield has been studied under drought conditions by many investigators. Broad sense heritability for days to heading and grain yield were high for these two traits (Calzolari *et al.*, 1980, Kheiralla *et al.*, 1993, Wiersma *et al*., 2001 and Shamroukh, 2006). On the other hand, narrow sense heritability values were moderate for days to heading and grain yield/plant (Attia, 2003 and Shamroukh, 2006). Information on association of earliness and grain yield and its components can help breeders for increasing the selection efficiency (Menshawy, 2007).

This study aimed to investigate the response to selection in the early segregating generations for producing lines having high grain yield under drought stress, hopping to assist wheat breeders to identify superior genotypes.

Materials and methods

The present study was carried out in 2006 /07 and 2008/09 growing seasons, at Faculty of Agriculture, Sohag University, Egypt, to estimate the response to pedigree selection under normal and water stress conditions. The plant material was early generations of a bread wheat (*Triticum aestivum* L. em. Thel) population originated from the cross between Sids 4 and Tokwie. The genetic parameters were estimated in F3 and F4 generations. The pedigree and origin of the two parents and the check (Sahel 1) is presented in Table (1).

Table (1): The pedigree and origin of the two parents and the check (Sahel 1)

Parental name	Pedigree	Origin
Sids 4 (P1)	May'S'/Mon'S'//CMH74A.592/3/Giza 157*2	Egypt
Kasyon/glenn son-81 (P2)	------	ICARDA
Sahel 1	NS 732/PIMA//Veery'S'	ICARDA

In the 2006 / 07 season, 1000 plants of F_2 generation were grown in four non-replicated plots. Each plot consisted of 12 rows 3 m long, 20 cm apart and grain spaced 10 cm within row (average 30 individual plant/row). Also, the parents and the local check (Sahel 1, drought tolerant) were grown alongside each a row. The cultural practices were carried out as recommended for wheat production. Data were collected on 600 harvested plants. Data were recorded for No. of days to heading, No. of spikes/plant, 100 kernels weight and grain yield/plant for each individual plant. The 60 highest yielding plants and 60 earliest plants were selected. An equal number of grains from each plant (600 plants) were bulked to give F_3 random bulk sample.

In the 2007/08 season, two field experiments were conducted each in a

randomised complete block design of four replications. The first experiment did not receive any irrigation after jointing stage (drought stress "D"), while the other one was grown in supplemental water applied regularly as recommended (Normal "N"). Each selected plant from the F_2 generation was planted in the two experiments. Each experiment comprised 120 F_3 families (60 high yielding and 60 early families). At the end of the season, the 15 earliest and 16 high yielding families were identified from both experiments after the statistical analysis. The best plant from each of these families was saved (31 plants; 15 for earliness and 16 high yielding).

In 2008/09 season (F_4 generation), two field experiments were conducted as in the previous season. The selected plants from the F_3 generation (31 plants) were evaluated under stress and normal irrigation conditions; along with the two parents, bulk sample and the check cultivar Sahel 1. Days to 50% heading, spike length, no. of spike/plant, no. of kernel/spike, 100-kernel weight and grain yield/plant were recorded.

The analysis of variance for randomized complete block design was carried out according to Snedecor and Cochran (1980).

1- The observed and expected response to selection were calculated using the following formula :

Observed response**:** the difference between the mean of the selected families and the mean of bulk population, best parent and check cultivar.

Expected response = $i\ H_n\ \sigma\ p$

where σ p = is the phenotypic standard division, H = narrow sense heritability and i = selection intensity.The degrees of freedom and expected mean squares are present in Table (2).

Table (2): the analysis of variance and expected means of squares

Source of variance	D. F	M. S	E. M. S
Replication	r – 1	M_3	$\sigma^2e+ g\ \sigma^2r$
Genotypes	g – 1	M_2	$\sigma^2e + r\ \sigma^2g$
Error	(r –1) (g –1)	M_1	σ^2e

2 – The genotypic variance $\sigma 2g = M2 – M1/r$

3 – The phenotypic variance $\sigma 2p = \sigma 2g + \sigma 2e$

4 – The genotypic (G.C.V%) and phenotypic (P.C.V%) coefficient of variability were calculated as $\sigma g / \bar{x}$ and $\sigma p / \bar{x}$ respectively.

5 – Heritability in the broad sense (H) was estimated as the ratio of genotypic ($\sigma 2g$) to the phenotypic ($\sigma 2g + \sigma 2e$) variance according to Walker (1960).

6 – Heritability in the narrow sense was estimated using the correlation and offspring regression according to Smith and Kinman (1965) as follow:-

Parent – offspring generation	rxy	h = b/2rxy
F2, F3	3 /4	2 / 3 b F3, F2
F3, F4	7 / 8	4 / 7 b F4, F3

7 - The genetic parameters were estimated as outlined by Mather and Jinks (1977) and Falconer (1989).

8 – Comparisons among means were calculated by using revised L.S.D where, L.S.D = least significant difference, and was calculated as:

R L S $D\alpha = (t\text{-})\alpha * \sqrt{}\ (2MSE / r)$ (El Rawi and Khalafalla 1980)

Where t- is the t value from "minimum-average-risk t-table" at F-value of treatments, treatment df and experimental error df.

9 - The significance of observed direct and correlated response to selection was measured as deviation percentage of families mean from the bulk or the better parent or the check using L. S. D.

where, L.S.D = least significant differences between the bulk or the better parent or the check values and mean of the selected families, and was calculated as:

L. S. D = √ (MSE / r +MSE/fr) * tα

Where f: number of families' r: number of replicates

Drought susceptibility Index (S): was calculated according to the method of Fischer and Maurer (1978).

Results and Discussions

Evaluation of the base population (F2 – generation)

The results illustrated in Table (3) showed the average, range and coefficient of variation for number of days to 50 % heading, number of spikes/plant, 100-kernel weight, plant height and grain yield/plant in F2 plants under normal irrigated conditions. Number of days to 50 % heading ranged from 72.00 to 97.00 days with an average of 82.52 days and the coefficient of variation was 6.45% in F2 plants under normal conditions (Fig. 1. f). The average number of spikes/plant was 5.69 spikes/plant with a range from 2.00 to 12.00 spikes/plant and the coefficient of variation was 34.46% (Fig .1. g). The range of 100-kernel weight was 2.14 to 5.55 gm with an average of 3.50 gm and coefficient of variation was 15.02% (Fig. 1. h). Average grain yield/plant ranged from 1.50 to 18.85 gm with an average of 8.81 gm and coefficient of variation was 36.22% in F2 generation (Fig.1. j).

Table (3): Range, mean and coefficient of variation in F_2 plants for all studied traits.

Trait	Range	Means±S.E	C.V. %
1–Days to heading	72.00 – 97.00	82.52±0.22	6.45
2–No. of spikes / plant	2.00 – 12.00	5.69±0.08	34.46
3-100 kernel weight (gm)	2.14 – 5.55	3.50±0.02	15.02
4–Grain yield / plant (gm)	1.50 – 18.85	8.10±0.12	36.22

Selection for earliness

1-Response to direct selection for early heading under normal and water stress conditions.

Analysis of variance for all studied traits of early selected families (Table 4) showed highly significant differences among F3 and F4 families under normal and drought stress environments.

The average number of days to 50 % heading in F4 generation (Table 5) ranged from 68.50 to 82.50 with an average of 71.50 days and from 68.00 to 82.00 with an average of 70.90 days under normal and drought stress, respectively. Meanwhile, the average of number of days to heading was 74.75, 71.75 and 82.50 days for bulk population, early parent and the check, respectively under normal conditions and was 74.50, 71.25 and 81.75 days for bulk, early parent and the check, respectively under drought conditions. The five families, i.e., no. 3, 42, 55, 56 and 87 were significantly earlier than the earlier parent in days to heading under normal and drought conditions. But, all selected families were significantly earlier than the check under the two environments. Moreover, the values of earliness in these families for heading date varied from 0.38 days for family no. 3 or 87 to 1.88 days for family no. 42 and from 0.23 days for family no. 3 to 1.73 days for family no. 42 or 55 compared with earlier parent under normal and water stress environments, respectively. While, they varied from 7.38 days for family no. 14 to 12.63 days for family

no. 42 and from 6.73 days for family no. 14 to 12.23 days for family no. 42 or 42 compared with the check (Sahel 1) under normal and water stress conditions, respectively. Similar results were obtained by Oritiz Ferrara (1981) and pawar et al. (1986) who reported that pedigree method of selection was the better method in isolating genotypes for early flowering and similar results were obtained by Tammam et al. (2004a); Shamroukh (2006) and Aglan (2009).

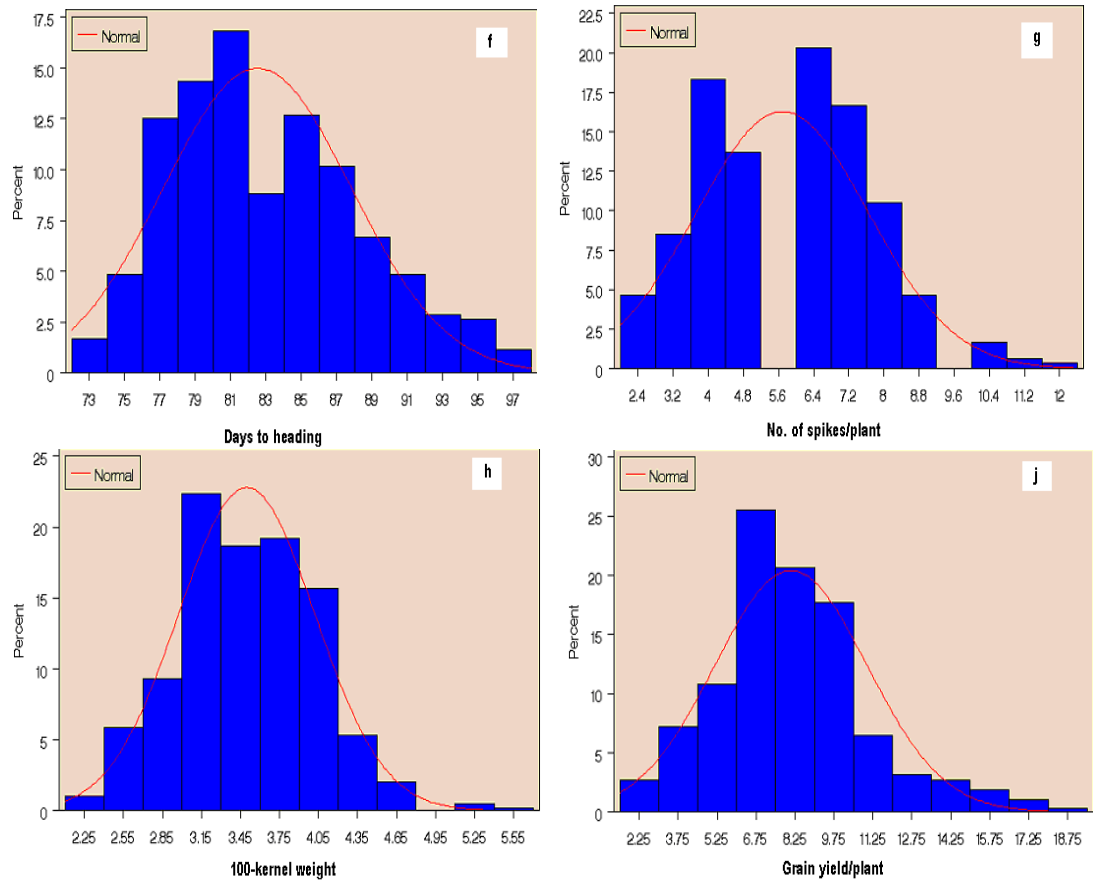

Figure (1). The normal distribution of days to heading (f), No. of spikes/plant (g), 100 kernel weight (h) and grain yield/plant (j) as traits on the F2 plants under normal conditions.

The observed and expected response to selection for days to heading are presented in (Table 6). It could be noticed that the observed response to selection were (-4.35, -0.35 and -13.33 %) and (-4.84, -0.50 and -13.28 %) in the F4 generation under normal and water stress conditions, respectively. Also, the observed direct response to selection for days to heading resulted in negative and highly significant observed gain compared with bulk and the check (Sahel 1) under the two conditions. On the other hand the expected responses to selection for heading date in F4 generation were 2.65 and 3.34% under normal and water stress conditions, respectively. These results were in agreement with those reported by Ehdaie and Waines (1989); Amin et al. (1992); Kheiralla et al (1993); Donmez et al. (2001) and Tammam et al. (2004a).

The magnitude of the phenotypic and genotypic coefficients of variability for days to heading (Table 7) were (3.89 and 3.37 %) and (4.05 and 3.57 %) in F3 families under normal and water stress, respectively. While, those values were (5.17 and 4.95 %) and (5.33 and 5.05 %) in F4 generation under favourable and drought stress, respectively. Similar results were obtained by Ehdaie and Waines (1989); Amin et al. (1992); Kheiralla (1993); Kheiralla et al. (1993); Tammam (1995);

Tammam et al. (2004a); Shamroukh (2006) and Abd El- Mohsen et al., (2012).

Table 4. Analysis of variance (ANOVA)

Generation	Treatments	S.o.v	D.F	Mean Squares: Direct selection	Correlated traits				
				Days to heading	Spike length	Number of spikes / plant	100 kernel weight	Number of kernels / spike	Grain yield / plant
Selection for early families									
F_3	N	Reps	3	6.53	0.33	0.07	0.03	10.47	0.40
		Families	63	29.63**	8.33**	6.88**	0.91**	182.10**	21.77**
		Error	189	2.26	0.11	0.15	0.03	8.59	0.87
	D	Reps	3	6.45	0.27	0.65	0.03	19.06	2.11
		Families	63	32.11**	9.59**	4.90**	0.91**	190.74**	13.92**
		Error	189	2.16	0.10	0.42	0.04	9.34	0.61
F_4	N	Reps	3	0.98	0.07	0.08	0.01	2.98	0.30
		Families	20	53.03**	15.58**	11.87**	1.17**	188.47**	11.05**
		Error	60	1.23	0.16	0.21	0.01	7.07	0.68
	D	Reps	3	1.47	0.08	0.56	0.01	2.56	0.36
		Families	20	54.74**	11.22**	9.05**	1.00**	132.38**	9.99**
		Error	60	1.51	0.14	0.17	0.03	6.47	0.55
Selection for highest yielding families									
					Correlated traits				Direct selection
F_3	N	Reps	3	0.59	0.23	0.23	0.02	8.84	0.63
		Families	63	107.4**	11.03**	6.23**	1.24**	186.91**	22.98**
		Error	189	2.57	0.11	0.16	0.03	8.01	0.87
	D	Reps	3	14.67	0.15	1.89	0.07	19.60	3.83
		Families	63	96.75**	9.38**	5.25**	1.32**	195.87**	11.48**
		Error	189	2.27	0.10	0.35	0.03	7.29	0.63
F_4	N	Reps	3	1.30	0.08	0.07	0.01	7.05	5.61
		Families	20	51.81**	15.79**	13.25**	1.01**	109.33**	24.94**
		Error	60	1.51	0.21	0.21	0.02	9.45	1.53
	D	Reps	3	0.68	0.18	0.29	0.04	0.99	0.17
		Families	20	48.99**	11.69**	9.04**	0.98**	126.82**	12.34**
		Error	60	1.52	0.14	0.12	0.03	7.40	0.72

The broad sense heritability for days to heading was high in the two generations under normal and drought stress (Table 7) and the values were 75.17 and 77.61 % in the F3 generation under normal and water stress, respectively, meanwhile, they were 91.35 and 89.83 % in F4 generation under normal and drought stress, respectively. The narrow sense heritabilities were 36.24 and 44.45 % in F4 generation under normal and drought stress, respectively. These results are in harmony with Calzolari et al. (1980); Ehdaie and Waines (1989); Amin et al., (1992); Tammam (1995); Tammam et al. (2004a); Aglan (2009) and Waqar-ul-haq and Akram (2010). However, Wiersma et al. (2001) found that the

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Table (5): Mean grain yield and other traits of early families in F_4 generation under normal (N) and drought (D) conditions.

Earliness families	Selection criteria		Correlated traits									
	Days to heading		Spike length		No. of spikes / plant		100 kernel weight		No. of kernels/ spike		Grain yield/ plant	
	N	D	N	D	N	D	N	D	N	D	N	D
3	70.00	69.50	17.43	14.53	4.35	3.65	5.81	4.77	48.41	43.99	16.96	11.93
4	71.75	71.00	16.90	14.25	5.00	4.55	4.64	3.87	61.35	41.92	16.09	10.40
14	73.75	73.50	15.85	14.20	4.75	4.40	5.78	4.90	58.53	47.61	16.97	13.87
32	72.75	72.25	11.98	10.25	9.30	8.30	4.62	3.97	54.60	43.93	19.08	15.06
33	72.75	72.25	11.73	9.75	8.90	7.20	4.78	3.69	51.78	43.61	19.28	12.24
35	72.50	72.25	13.45	11.98	6.35	6.00	5.01	4.22	56.66	50.95	18.65	14.51
36	73.25	73.00	11.40	10.18	8.30	7.60	5.24	4.25	44.21	38.19	16.84	12.31
37	71.75	71.00	11.93	10.73	6.70	5.65	4.64	3.99	58.68	45.11	14.64	11.38
42	68.50	68.00	11.95	11.68	8.00	7.15	4.18	3.45	60.65	56.18	15.22	12.54
46	72.75	71.75	13.43	11.03	8.00	7.40	4.71	3.97	58.56	54.63	16.02	13.12
49	71.00	70.25	12.45	11.45	6.00	5.55	4.14	2.98	38.30	34.19	13.85	9.23
52	72.00	71.50	17.45	15.23	5.25	4.60	5.67	4.67	45.04	40.50	17.33	12.70
55	69.25	68.00	13.25	11.48	9.55	8.50	4.60	4.08	41.13	37.52	17.00	13.87
56	69.00	68.75	15.28	13.78	5.70	5.00	5.13	4.36	52.88	44.95	18.41	14.43
79	71.00	70.00	13.05	11.18	7.40	6.80	4.85	4.15	49.06	41.97	15.79	11.92
87	70.00	69.00	12.98	10.15	5.30	4.85	3.84	3.12	47.09	42.42	13.07	9.36
96	73.50	73.25	12.90	11.10	6.15	5.60	4.88	4.04	45.47	39.46	14.57	11.25
Average	71.50	70.90	13.73	11.94	6.76	6.05	4.85	4.03	51.32	43.95	16.46	12.36
P1	71.75	71.25	15.75	14.15	4.05	3.60	5.60	4.62	58.38	53.02	17.46	13.11
P2	82.50	82.00	12.08	11.33	9.35	8.15	4.59	4.03	43.68	40.05	17.70	13.78
Bulk	74.75	74.50	13.00	12.70	7.50	6.63	4.92	3.97	49.97	43.92	16.90	12.91
Sahel 1	82.50	81.75	11.82	10.97	7.85	6.95	4.29	3.98	52.48	46.32	17.08	13.38
$RLSD_{0.05}$	1.37	1.52	0.49	0.46	0.57	0.51	0.12	0.21	3.37	3.33	1.08	0.97
$RLSD_{0.01}$	1.80	1.99	0.65	0.61	0.74	0.67	0.16	0.28	4.08	4.62	1.42	1.27

Table (6): The observed and expected response to selection in F_4 generation for all studied traits of early families under normal (N) and drought stress (D) conditions.

Trait	Condition	Response to selection as deviation from						Expected response	
		Bulk		Best parent		Check (Sahel 1)			
		unit	%	unit	%	unit	%	unit	%(from mean)
		Direct response							
Days to heading	]	-3.25**	-4.35**	-0.25	-0.35	-11.00**	-13.33**	1.90	2.65
	]	-3.60**	-4.84**	-0.35	-0.50	-10.85**	-13.28**	2.37	3.34
		Correlated response in							
Spike length	]	0.73**	5.60**	-2.02**	-12.84**	1.91**	16.14**	1.77	12.87
	]	-0.76**	-6.02**	-2.21**	-15.65**	0.97**	8.80**	1.31	11.00
No. of spikes/plant	]	-0.74**	-9.80**	-2.59**	-27.65**	-1.09**	-13.83**	1.39	20.49
	]	-0.58**	-8.79**	-2.10**	-25.80**	-0.90**	-12.99**	1.32	21.82
100 kernel weight	]	-0.07	-1.40**	-0.75**	-13.37**	0.56**	13.08**	0.45	9.21
	]	0.06	1.45**	-0.59**	-12.82**	0.05	1.19**	0.36	9.03
No. of kernels/spike	]	1.35	2.70*	-7.06**	-12.10**	-1.16	-2.22	5.17	10.07
	]	0.03	0.07	-9.07**	-17.11**	-2.37	-5.12**	3.79	8.63
Grain yield/plant	]	-0.44	-2.62**	-1.24**	-7.02**	-0.62	-3.65**	1.44	8.77
	]	-0.55	-4.27**	-1.42**	-10.31**	-1.02**	-7.63**	1.34	10.82

* & **Significant at 5 % and 1 % levels of probability, respectively.

Table (7): Genetic parameters for days to heading of the early selected families and grain yield/plant of the highest yielding selected families in F_3 and F_4 generations under normal and drought conditions.

Items	Selection for earliness				Selection for high yield			
	Days to heading				Grain yield/plant			
	Normal		Drought		Normal		Drought	
	F_3	F_4	F_3	F_4	F_3	F_4	F_3	F_4
Phenotypic Var.	9.10	14.18	9.65	14.82	6.90	7.38	3.74	3.62
Genotypic Var.	6.86	12.95	7.49	13.31	5.66	5.85	2.79	2.91
P.C.V. %	3.89	5.17	4.05	5.33	18.63	13.27	18.72	13.03
G.C.V. %	3.37	4.95	3.57	5.05	16.86	11.82	16.18	11.67
Heritability								
Broad – sense	75.17	91.35	77.61	89.83	81.98	79.31	74.71	80.24
Narrow – sense	--	36.24	--	44.45	--	49.10	--	57.01

broad sense heritability for days to heading was 87 %. Shamroukh (2006), also, indicated that broad sense heritability in Pop. I was 94.92 and 95.12 in F3 and F4 generations under drought conditions, respectively, meanwhile, in population II, it was 94.35 and 95.47 under drought condition in F3 and F4 generations, respectively. Moreover, narrow sense heritability for days to heading in the two populations ranged from (36.19% to 30.79%) and (32.92 to 27.86%) under normal and drought stress, respectively

II-2-Effects of selection for earliness under normal and water stress conditions on correlated traits.

The average spike length of early selected families in F4 generation (Tables 5) ranged from 11.40 to 17.45 with an average of 13.73 cm and from 9.75 to 15.23 with an average of 11.94 cm under normal and drought conditions, respectively. The average of spike length for bulk population, better parent and check were (13.00, 15.75 and 11.82 cm) and (12.70, 14.15 and 10.97 cm) under normal and drought conditions, respectively. Three families, i.e., no. 3, 4 and 52 under normal condition and one family, i.e., no. 52 under drought stress were significantly longer than the better parent. Twelve families, i.e., no. 3, 4, 14, 35, 46, 49, 52, 55, 56, 79, 87 and 96 under normal condition and nine families, i.e., no. 3, 4, 14, 35, 42, 49, 52, 55 and 56 under drought condition were significantly longer than the check.

The range of no. of spikes/plant (Tables 5) varied from 4.05 to 9.55 with an average of 6.76 spikes/plant and from 3.60 to 8.50 with an average of 6.05 spikes/plant in F4 generation under the two environments, respectively. The average of no. of spikes/plant for bulk population, better parent and check were (7.50, 9.35 and 7.85 spikes/plant) and (6.63, 8.15 and 6.95 spikes/plant) under normal and drought conditions, respectively. Three families, i.e., no. 32, 33 and 55 under normal condition and three families, i.e., no. 32, 36 and 55 in no. of spikes/plant significantly exceeded the check under drought stress.

The average 100-kernel weight in F4 generation (Tables 5) ranged from 3.84 to 5.81 with an average of 4.85 and from 2.98 to 4.90 with an average of 4.03 gm under the two conditions. While the average of 100-kernel weight was 4.92, 5.60 and 4.29 gm for bulk population, better parent and check, respectively under normal condition and was 3.97, 4.62 and 3.98 gm for bulk population, better parent and check, respectively under drought condition. Moreover, two families, i.e., no. 3 and 14 under normal condition and one family, i.e., no. 14 under drought condition were significantly higher than the better parent in 100-kernel weight. Meanwhile, six families surpassed the check under drought condition.

The average no. of kernels/spike for F4 generation (Table 5) ranged from 38.30 to 61.35 with an average of 51.32 and 34.19 to 56.18 with an average of 43.95 under the two environments. The average of no. of kernels/spike for bulk population, better parent and check were (49.97, 58.38 and 52.48) and (43.92, 53.02 and 46.32) under normal and drought conditions, respectively. Six families, i.e., no. 4, 14, 35, 37, 42 and 46 under normal condition and three families, i.e., no. 35, 42 and 46 under drought stress of the earliness selection for no. of kernels/spike significantly exceeded the check.

The average grain yield/plant of early selected families in the F4 generation (Table 5) ranged from 13.07 to 19.28 with an average of 16.46 g/plant and 9.23 to 15.06 with an average of 12.36 g/plant under the two environments. The average of grain yield/plant for bulk, better parent and check were (16.90, 17.70 and 17.08) and (12.91, 13.78 and 13.38) under normal and drought conditions, respectively. Two families, i.e., no. 32 and 33 in the early selected families under normal condition and one family, i.e., no. 32 under drought stress were significantly out-yielded the better parent. Four families, i.e., no. 32, 33, 35 and 56 under normal condition and three families, i.e., no. 32, 35 and 56 under drought stress significantly exceeded the check for grain yield/plant.

II-3- Drought susceptibility index (DSI).

Data of drought susceptibility index for families selected for earliness (Table 8) cleared that the values of drought susceptibility index ranged from 0.79 to 1.28 and from 0.70 to 1.46 in F3 and F4 generations, respectively. Seven families in F3 and ten families in F4 gave low values of susceptibility for drought stress (DSI < 1), but seven families i.e no. 14, 32, 35, 42, 46, 55 and 56 exhibited low values of drought susceptibility index in the two generations. Moreover, the families no. 32, 35, 55 and 56 have high yield under drought and highly tolerant for drought in the two generations.

III-Selection for grain yield:

III-1-Response to direct selection for grain yield under normal and water stress conditions.

The analysis of variance in Table (4) revealed highly significant differences among F3 and F4 families for all studied traits of highest yielding selected families under normal and water stress conditions.

The range of grain yield/plant of the highest yielding selected families under normal condition in the F4 generation (Table 9) varied from 16.90 to 24.44 with an average of 21.22 g/plant and from 12.21 to 18.61 with an average of 14.91 g/plant under drought condition. The average of grain yield/plant in F4 generation for bulk population, better parent and check (Sahel 1) were (16.90, 17.70 and 17.08 g/plant) and (12.91, 13.78 and 13.38 g/plant) under normal and drought stress conditions, respectively. All selected families of highest yielding selected families except (no. 9, 10, 32, 33, 35 and 56) under normal condition in grain yield/plant were significantly higher than the better parent. Also there were eight families (no. 1, 17, 18, 20, 23, 26, 28 and 35) under drought stress that were significantly out-yielded the high yielding parent. All selected families under normal condition and all selected families under drought stress except (no. 1 and 42) significantly exceeded the check (Sahel 1) in grain yield/plant . These results indicated that pedigree method of selection was effective in grain yield improvement as found in population I. The results are in accordance with those obtained by Seitzer and Evans (1978); Pawar et al. (1986); Tammam et al. (2004a) and Shamroukh (2006), who showed that using pedigree method of selection was the best and most effective method in improving grain yield/plant.

Data in Table (10) showed that the observed responses to selection of the high yield families compared with bulk, better parent and check under normal and drought stress conditions were (25.57, 19.89 and 24.24 %) and (15.52, 8.23 and 11.46 %) in F4 families under normal and water stress conditions, respectively. Also, the observed direct response to selection for grain yield/plant resulted in positive and highly significant observed gain compared with bulk and the check (Sahel 1) under normal and drought stress conditions. Moreover, the expected responses to selection for grain yield/plant in F4 generation were 8.78 and 10.19% under normal and drought stress conditions, respectively. These results were adequate to those found by Hamada (1988), who stated that the predicted gain was 10.87 % in the F3 and 4.99 % in the F4 generation and actual gain was closely agreed with predicted gain. These results are in agreement with many studies: Mahdy (1988); Kheiralla (1993); Tammam (1995) and Tammam et al. (2004a). Shamroukh (2006) found that expected response to selection of F4 families in population I under normal and drought stress conditions for grain yield/plant were 0.97 and 0.64 gm meanwhile, in population II, they were 0.59 and 0.64 gm.

The phenotypic coefficient of variability (PCV) under drought stress (Table 7) was 3.74 % in F3 families and 3.62 % in F4, while under normal treatment, it was 6.90 and 7.38 % in F3 and F4 families, respectively. The genotypic coefficient of variability (GCV) was 2.91 % in F3 families and 2.79 % in F4 under drought stress, whereas under normal conditions it was 5.66 and 5.85% in F3 and F4 families, respectively. These results are in agreement with those obtained by Nanda et al. (1990); Amin et al. (1992) and Abd El-Mohsen et al., (2012). Tammam (1995)

Table (8): Drought susceptibility index (DSI).

Selection for earliness							Selection for grain yield						
No.	F_3 generation			F_4 generation			No.	F_3 generation			F_4 generation		
	G.Y		DSI	G.Y		DSI		G.Y		DSI	G.Y		DSI
	N	D		N	D			N	D		N	D	
3	12.55	8.92	1.11	16.96	11.93	1.19	1	17.72	13.74	0.80	21.40	16.65	0.74
4	13.08	8.77	1.27	16.09	10.40	1.41	6	17.48	11.41	1.24	22.10	12.72	1.41
14	12.22	9.71	0.79	16.97	13.87	0.73	9	15.05	11.75	0.78	18.13	12.21	1.09
32	15.09	11.77	0.85	19.08	15.06	0.84	10	15.74	12.37	0.76	18.43	14.60	0.70
33	16.08	10.79	1.27	19.28	12.24	1.46	17	16.24	11.32	1.08	22.78	16.89	0.86
35	15.37	12.00	0.84	18.65	14.51	0.89	18	16.13	13.03	0.69	21.01	17.10	0.62
36	12.56	8.74	1.17	16.84	12.31	1.08	19	18.79	11.46	1.39	22.14	14.28	1.18
37	13.12	9.56	1.04	14.64	11.38	0.89	20	21.26	16.34	0.83	24.26	18.61	0.78
42	12.37	9.74	0.82	15.22	12.54	0.70	21	20.63	12.62	1.39	23.03	13.73	1.35
46	13.28	10.54	0.79	16.02	13.12	0.72	23	18.86	12.50	1.21	24.44	15.27	1.25
49	11.94	7.96	1.28	13.85	9.23	1.33	26	15.87	12.31	0.80	21.77	16.62	0.79
52	12.56	8.90	1.12	17.33	12.70	1.07	28	19.57	12.92	1.21	23.64	15.34	1.17
55	14.05	11.17	0.79	17.00	13.87	0.74	30	15.89	10.63	1.18	22.18	13.29	1.34
56	14.53	11.50	0.80	18.41	14.43	0.86	32	15.09	11.77	0.79	19.08	15.06	0.70
79	11.18	7.86	1.14	15.79	11.92	0.98	33	16.08	10.79	1.18	19.28	12.24	1.22
87	11.15	7.64	1.21	13.07	9.36	1.14	35	15.37	12.00	0.78	18.65	14.51	0.74
96	10.97	7.70	1.14	14.57	11.25	0.91	56	14.53	11.50	0.74	18.41	14.43	0.72

Table (9): Mean grain yield and other traits of the highest yielding families in F_4 generation under normal (N) and drought (D) conditions.

Selected families	Selection criteria		Correlated traits									
	Grain yield/plant		Days to heading		Spike length		No. of spikes / plant		100 kernel weight		No. of kernels/ spike	
	N	D	N	D	N	D	N	D	N	D	N	D
1	21.40	16.65	75.00	74.50	13.33	11.58	10.20	8.55	5.82	4.80	51.84	45.42
6	22.10	12.72	74.75	74.25	12.68	11.00	9.70	7.80	5.00	4.34	54.19	42.60
9	18.13	12.21	78.25	75.75	12.18	11.25	7.45	6.95	4.21	3.28	58.62	47.40
10	18.47	14.60	77.75	76.50	11.83	9.95	7.60	6.90	4.18	3.72	60.14	50.49
17	22.78	16.89	77.50	76.25	14.48	12.53	9.96	8.85	5.04	4.74	45.09	38.37
18	21.01	17.10	82.50	82.00	16.25	14.65	7.50	7.00	5.76	4.67	51.99	45.49
19	22.14	14.28	79.50	79.75	17.58	14.50	7.05	6.10	4.82	4.38	61.05	55.66
20	24.26	18.61	78.50	76.75	12.00	11.25	11.75	10.15	5.58	4.78	51.97	46.71
21	23.03	13.73	75.75	75.00	16.93	14.20	8.40	6.40	5.57	5.11	52.67	44.70
23	24.44	15.27	75.75	75.00	12.50	10.50	9.95	9.45	5.70	5.04	61.43	55.00
26	21.77	16.62	76.00	75.50	17.08	15.36	6.50	6.00	4.84	4.08	63.95	58.99
28	23.64	15.34	76.25	76.00	12.08	10.73	10.30	8.00	4.82	4.15	60.70	57.46
30	22.18	13.29	77.00	76.50	12.83	11.25	8.80	7.50	4.92	4.22	56.29	49.15
32	19.08	15.06	72.75	72.25	11.98	10.25	9.30	8.30	4.62	3.97	54.60	43.93
33	19.28	12.24	72.75	72.25	11.73	9.75	8.90	7.20	4.78	3.69	51.78	43.61
35	18.65	14.51	72.50	72.25	13.45	11.98	6.35	6.00	5.01	4.22	56.66	50.95
56	18.41	14.43	69.00	68.75	15.28	13.78	5.70	5.00	5.13	4.36	52.88	44.95
Average	21.22	14.91	75.97	75.25	13.77	12.03	8.55	7.42	5.04	4.33	55.64	48.29
P1	17.46	13.11	71.75	71.25	15.75	14.15	4.05	3.60	5.60	4.62	58.38	53.02
P2	17.70	13.78	82.50	82.00	12.08	11.33	9.35	8.15	4.59	4.03	43.68	40.05
Bulk	16.90	12.91	74.75	74.50	13.00	12.70	7.50	6.63	4.92	3.97	49.97	43.92
Sahel 1	17.08	13.38	82.50	81.75	11.82	10.97	7.85	6.95	4.29	3.98	52.48	46.32
$RLSD_{0.05}$	1.62	1.11	1.52	1.53	0.57	0.46	0.57	0.43	0.18	0.21	4.02	3.56
$RLSD_{0.01}$	2.13	1.46	1.99	1.99	0.74	0.61	0.74	0.56	0.23	0.28	5.28	4.67

reported that the PCV was 46.80 in the F2, 23.61 in the F3 and 15.70 in the F4 generation, while the GCV ranged from 5.13 % in the F5 to 36.42 % of the F2 plants. Shamroukh (2006) found that the PCV under normal conditions were 5.34 and 4.31 % in the F3 and F4 generations, while it was 2.35 and 1.65% in F3 and F4 generations under drought stress, respectively. The genotypic values GCV under normal conditions were 4.77 and 3.59 % in the F3 and F4 generations, while it was 2.04 and 1.56% for F3 and F4 generations under drought stress, respectively.

The broad sense heritability for grain yield/plant under two environmental conditions (Table 7) were high (81.98 and 74.71%) in the F3 families under normal and water stress, respectively as well as 79.31 and 80.24% in F4 generation under normal and drought stress, respectively. While the narrow sense heritability was 49.10 and 57.01 % in F4 generation under the two studied conditions, respectively. These results are in line with those obtained by Sidwell et al. (1976); May and van Sanford (1992); Wiersma et al. (2001); Utz et al. (2001); Tammam et al. (2004a); Memon et. Al., (2007) and Hussain et. al., (2013). Moreover, Shamroukh (2006) who found that the broad sense heritability for grain yield / plant under drought condition was high (86.86 and 94.83) in the F3 and F4 generations, respectively. The narrow sense one under drought stress ranged from 23.13 to 51.73 .

2-Effects of selection for grain yield under normal and water stress conditions on correlated traits

The average of days to heading for highest yielding selected families in F4 generation (Table 9) ranged from 69.00 to 82.50 with an average of 75.97 days under normal condition and from 68.75 to 82.00 with an average of 75.25 under water stress condition. Furthermore, the average of days to heading in F4 generation for bulk population, early parent and check (Sahel 1) were (74.75, 71.75 and 82.50 days) and (74.50, 71.25 and 81.75 days) under normal and drought conditions, respectively. The results showed that one family, i.e., no. 56 under normal and drought conditions were significantly earlier than the earlier parent in days to heading meanwhile all selected families except (no. 18) were significantly earlier than the check (Sahel 1) under two environments.

The average spike length in F4 generation (Table 9) ranged from 11.73 to 17.58 with an average of 13.77 cm and from 9.75 to 15.36 with an average of 12.03 cm under the two environments, respectively. The average of spike length for bulk population, better parent and check were (13.00, 15.75 and 11.82 cm) and (12.70, 14.15 and 10.97 cm) under normal and drought conditions, respectively. Three families, i.e., no. 19, 21 and 26 under normal condition and two families (no. 18 and 26) under drought stress were significantly longer than the better parent. However, all selected families except (no. 9, 10, 20, 28, 32 and 33) under normal condition and eight families, i.e., no. 1, 17, 18, 19, 21, 26, 35 and 56 under drought stress condition were significantly longer than the check.

The average of no. of spikes/plant for bulk population, better parent and check (Table 9) were (6.65, 8.65 and 6.85 spikes/plant) and (5.60, 7.85 and 5.90 spikes/plant) under normal and drought conditions, respectively. The range of no. of spikes/plant varied from 4.05 to 11.75 with an average of 8.55 spikes/plant and from 3.60 to 10.15 with an average of 7.42 spikes/plant in F4 generation under the two environments, respectively. Furthermore, the average of no. of spikes/plant for bulk population, better parent and check were (7.50, 9.35 and 7.85 spikes/plant) and (6.63, 8.15 and 6.95 spikes/plant) under normal and drought conditions, respectively. Five families, i.e., no. 1, 17, 20, 23 and 28 under normal condition and three families, i.e., no. 17, 20 and 23 under drought stress of the highest yielding selection significantly exceeded the better parent. While, nine families, i.e., no. 1, 6, 17, 20, 23, 28, 30, 32 under normal and drought conditions surpassed the check for no. of spikes/plant.

The average of 100-kernel weight in F4 generation (Table 9) ranged from 4.18 to 5.82

with an average of 5.04 and from 3.28 to 5.11 with an average of 4.33 gm under the two conditions, respectively. While, the average of 100-kernel weight were 4.92, 5.60 and 4.29 gm for bulk population, better parent and check (Sahel 1), respectively under normal condition and were 3.97, 4.62 and 3.98 gm for bulk population, better parent and check, respectively under drought condition. Two families (no. 21 and 23) in 100-kernel weight under drought stress condition were significantly higher than the better parent. Meanwhile, eleven families, i.e., no. 1, 6, 17, 18, 19, 20, 21, 23, 30, 35 and 56 surpassed the check under stress condition.

Mean no. of kernels/spike in F4 generation (Table 9) ranged from 43.68 to 63.95 with an average of 55.64 and from 38.37 to 58.99 with an average of 48.29 under the two conditions, respectively. The average of no. of kernels/spike for bulk population, better parent and check were (49.97, 58.38 and 52.48) and (43.92, 53.02 and 46.32) under normal and drought stress conditions, respectively. One family, i.e., no. 26 under normal condition and two families (no. 26 and 28) under water stress condition surpassed the better parent. Six families, i.e., no. 10, 19, 23, 26, 28 and 35 under normal and drought conditions significantly exceeded the check. These results showed that direct selection for grain yield was relatively effective in improving no. of kernels/spike under drought condition. Also, they reflect the positive associations between grain yield and no. of kernels/spike.

These results showed that the selection for high yield under water stress condition was more effective in improving grain yield/plant in the dry land through earliness and some major yield components. These results are in agreement with those obtained by Kheiralla, 1993; Tammam, 1995; Tammam et al., 2004a; Shamroukh, 2006; Memon et. Al., (2007) and Hussain et. al.,(2013).

3- Drought susceptibility index (DSI).

The values of drought susceptibility (Table 8) ranged from 0.69 to 1.39 and from 0.62 to 1.41 in F3 and F4 generations, respectively. The results showed that nine families in F3 and F4 generations gave low values of drought susceptibility index (DSI < 1), but the eight families no 1, 10, 8, 20, 26, 32, 35 and 72 produced the low values of susceptibility index in F3 and F4 generation, (0.80 and 0.74), (0.76 and 0.70), (0.69 and 0.62), (0.83 and 0.78), (0.80 and 0.79), (0.79 and 0.70), (0.78 and 0.74) and (0.74 and 0.72), respectively. Superior families for drought tolerance of the selected families gave the low values of drought susceptibility index and the highest grain yield under drought. These families were no. 1, 18 and 20 in F3 and F4 generations and no. 17, 26 and 32 in F4 generation.

A highly significant and negative correlation (Table 11) was found between the mean grain yield under water stress condition and drought susceptibility index (r =-0.63**). This would indicate that about 50% of variation in drought susceptibility in this set of genotypes could be ascribed to variation in yield potential, as defined by DSI, need not be have a high yield since DSI provides a measure of tolerance based on minimization of yield loss under stress, rather than no stress yield as pointed by Bruckner and Frohberg (1987). These results are in accordance with those reported by Bidinger et al. (1987), Kheiralla (1994) and Shamroukh (2006).

Finally it could be concluded that drought susceptibility index indicated that drought tolerance could be due to high yield potential and / or low susceptibility to stress (DSI < 1). The six families, i.e., no. 1, 17, 18, 20, 26 and 32 produced relatively high grain yield under drought stress and low drought susceptibility index (tolerance for drought). These genotypes could be used as source of drought tolerance or factors contributing to general adaptation and can be used in breeding programs to produce lines or cultivars having high grain yield ability and high tolerance for drought stress. These results are in agreement with those obtained by Kheiralla, 1993; Farshadfar et al., 2001; Tammam et al., 2004b and Hasan and Tacettin, 2010.

Table (10): Observed and expected response to selection in F_4 generation for all studied traits of the highest yielding families under normal (N) and drought stress (D) conditions.

Trait	Condition	Response to selection as deviation from							
		Bulk		Best patent		Check (Sahel 1)		Expected response	
		Unit	%	Unit	%	Unit	%	Unit	%(from families mean)
		Direct response							
Grain yield / plant	N	4.32**	25.57**	3.52**	19.89**	4.14**	24.24**	1.86	8.78
	D	2.00**	15.52**	1.13**	8.23**	1.53**	11.46**	1.52	10.19
		Correlated response in							
Days to heading	N	1.22*	1.63**	4.22**	5.88**	-6.53**	-7.91**	1.21	1.59
	D	0.75	1.01	4.00**	5.61**	-6.50**	-7.95**	1.23	1.63
Spike length	N	0.77**	5.94**	-1.98**	-12.56**	1.95**	16.51**	1.30	9.47
	D	-0.67**	-5.29**	-2.12**	-14.99**	1.06**	9.65**	1.15	9.52
No. of spikes / plant	N	1.05**	14.05**	-0.80**	-8.52**	0.70**	8.96**	1.51	17.69
	D	0.79**	11.92**	-0.73**	-8.95**	0.47**	6.77**	1.20	16.18
100 kernel weight	N	0.12	2.54**	-0.56**	-9.91**	0.75**	17.60**	0.35	6.98
	D	0.36*	8.94**	-0.30*	-6.39**	0.35*	8.67**	0.34	7.81
No. of kernels/spike	N	5.67**	11.34**	-2.74	-4.70**	3.16*	6.02**	3.12	5.61
	D	4.37**	9.94**	-4.73**	-8.93**	1.97	4.25**	3.50	7.26

* & **Significant at 5 % and 1 % levels of probability, respectively.

Table (11): Mean days to heading, grain yield/plant under normal (DHn) and water stress conditions (DHs) and drought susceptibility index (DSI) and correlations (r) between them of the highest yielding families in F_4 generation.

Selected families	DSI	DHn	DHs	GYn	GYs
1	0.74	75.00	74.50	21.40	16.65
6	1.41	74.75	74.25	22.10	12.72
9	1.09	78.25	75.75	18.13	12.21
10	0.70	77.75	76.50	18.43	14.60
17	0.86	77.50	76.25	22.78	16.89
18	0.62	82.50	82.00	21.01	17.10
19	1.18	79.50	79.75	22.14	14.28
20	0.78	78.50	76.75	24.26	18.61
21	1.35	75.75	75.00	23.03	13.73
23	1.25	75.75	75.00	24.44	15.27
26	0.79	76.00	75.50	21.77	16.62
28	1.17	76.25	76.00	23.64	15.34
30	1.34	77.00	76.50	22.18	13.29
32	0.70	72.75	72.25	19.08	15.06
33	1.22	72.75	72.25	19.28	12.24
35	0.74	72.50	72.25	18.65	14.51
56	0.72	69.00	68.75	18.41	14.43
r		0.01	0.03	0.41	-0.63**
r			0.99**	0.38	0.33
r				0.42	0.34
r					0.44

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