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EVALUATION OF DROUGHT RESISTANCE INDICES IN BREAD WHEAT UNDER IRRIGATED AND NON-IRRIGATED CONDITIONS

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ABSTRACT

The objective of this study was to evaluate the ability of several selection indices to identify drought resistant genotypes under a variety of environmental conditions. Twelve bread wheat genotypes differing in yield performance were grown in separate experiments under non-irrigated and irrigated conditions in 2006/2007 and 2007/2008 seasons. Nine selection indices including stress susceptibility index (SSI), yield stability index (YSI), superiority measure (*Pi*), mean productivity (MP), tolerance (TOL), stress tolerance index (STI), geometric mean productivity (GMP), yield index (YI), and absolute rank (Di) were calculated based on grain yield under non-irrigated and irrigated conditions. The results showed that under stress *Pi*, MP, STI, GMP and YI were more effective in identifying high yielding genotypes in both non-irrigated and irrigated conditions. It is concluded that the use of different concepts of selection indices will lead to different rankings of genotypes. So, wheat breeders should therefore, take the stress severity of the environment into account in choosing an index.

Key words: Drought; Resistance indices; Bread wheat; Irrigated and non-irrigated conditions, rank correlation.

INTRODUCTION

Under dry areas the major limitation to cereal yield is the amount of available water (Auston 1987). Also, Ashraf and Harris (2005) mentioned that insufficient water is the primary limitation to wheat production worldwide. However, quantification of drought tolerance should be estimated on grain yield under dry conditions in the absence of an understanding of specific mechanisms of tolerance. It is worth while that, relative yield performance of genotypes in drought-stressed and more favorable environments seems to be a common starting point in the identification of traits related to drought tolerance and the selection of genotypes for use in breeding for dry environments (Clarke *et al.*, 1992). According to Fernandez (1992), genotypes can be divided into four groups based on their yield response to stress conditions: (1) genotypes producing high yield under both water stress and non-stress conditions (group A), (2) genotypes with high yield under non-stress (group B) or (3) stress (group C) conditions and (4) genotypes with poor performance under both stress and non-stress conditions (group D). The question is: should breeders do selection under both potential and stress conditions or in either environment alone? Some researchers believe in selection under favorable condition (Richards, 1996; Van Ginkel *et al.*, 1998; Rajaram and Van Ginkle, 2001 and Betran *et al.*, 2003). Selection in the target stress condition has been highly recommended too (Ceccarelli, 1987, Ceccarelli and Grando, 1991 and Rathjen, 1994). Several researchers have chosen the mid-way and believe in selection under both favorable and stress conditions (Fischer and Maurer, 1978, Clarke *et al.*, 1992, Nasir Ud-Din *et al.*, 1992, Fernandez, 1992, Byrne *et al.*, 1995 and Rajaram and Van Ginkle, 2001).

To differentiate genotypes for drought resistance, several selection indices have been suggested on the basis of a mathematical relationship between favorable and stress conditions (Clarke *et al.*, 1984 and Huang, 2000). For examples, tolerance (TOL) by McCaig and Clarke (1982) and Clarke *et al.* (1992), mean productivity (MP) by McCaig and Clarke, (1982) stress susceptibility index (SSI) by Fischer and Maurer (1978), geometric mean productivity (GMP) and stress tolerance index (STI) by Fernandez (1992) and absolute ranks (Di) by Huhan and Nassar (1989). They have all been working under various conditions. Fischer and Maurer (1978) explained that genotypes with an SSI of less than a unit are drought resistant, since their yield reduction in drought condition is smaller than the mean yield reduction of all genotypes. Meanwhile, Bruckner and Frohberg, (1987), Bansal and Sinha (1991) concluded that species with a smaller linear regression coefficient (*b*) have a higher drought resistance. On the other hand, the superiority measure (*Pi*) proposed by Lin and Binns (1988). This technique utilizes the highest-yielding genotypes within each environment as a reference point. Cultivars with the largest yield difference than the reference would have the highest *Pi* value.

The main objective of this study was to evaluate 12 bread wheat genotypes for grain yield/fed. Under irrigated and non irrigated conditions by using several selection indices in order to identify the most suitable indices/ Genotypes.

MATERIALS AND METHODS

Twelve bread wheat genotypes including two local wheat cultivars (Sakha 8 and Sahel 1) were chosen for study based on their reputed differences in yield performance under irrigated and non-irrigated conditions. The experiments were conducted at the Faculty of Agriculture, Cairo University, Agriculture Experiment and Research Station, during two successive seasons of 2006/2007 in Giza governorate (30.029°N 31.207°E). The soil texture was silt-loam (21% clay, 54% silt and 25% sand) with 3.2% organic matter and a pH of 7.84. Absorbable N, P and K were 1.12%, 0.08% and 0.20%, respectively. The pedigree and origin of the studied genotypes are listed in Table (1). The twelve genotypes were planted in a randomized complete block design with four replications and grown under irrigated and non irrigated conditions. Irrigated plots were watered at planting, tillering, jointing, flowering and grain filling stages. Non-irrigated plots received water only at planting and tillering. Sowing was done in November in all experiments. Each plot consisted of four rows, 3 m long. Distance between plants within rows was 20 cm. Ten plants were randomly chosen from each plot to measure: plant height, spike length, and spikelets/spike. The grain yield was measured by harvesting of the central two rows of each plot at crop maturity.

Statistical technique:

Normality distributions in each trait were checked out by the Wilk Shapiro test (Neter *et al.*, 1996). A combined analysis of variance was conducted for the two seasons according to Gomez and Gomez (1984). Homogeneity test of variances were performed according to procedures reported by Gomez and Gomez (1984). Data were statistically analyzed using ANOVA and LSD value which was employed for the mean comparisons in the MSTAT-C software package (Freed *et al.*, 1989), and SPSS (1999) computer software. The combined data of yield and yield components over both seasons were used the following statistical procedures.

Drought resistance indices were calculated using the following relationships:

(1) $SSI \frac{1-(Y_s/Y_p)}{1-(\bar{Y}_s/\bar{Y}_p)}$ (Fischer and Maurer, 1978).

where Ys is the yield of cultivar under stress, Yp the yield of cultivar under irrigated condition, $\bar{Y}s$ and $\bar{Y}p$ the mean yields of all cultivars under stress and non-stress conditions, respectively, and $1-(\bar{Y}_s/\bar{Y}_p)$ is the stress intensity.

Table (1): Names, pedigrees and origins of the studied genotypes.

No.	Genotypes	Pedigree	Origin*
1	L.R. 39	TEVEVEEE"S"/SHUHA"S"	Egypt
2	L.R. 40	KAUZ/STAR	Sudan
3	L.R. 42	BSP93-21 OSAF	Sudan
4	L.R. 43	TEVEE"S"/TDINA	Sudan
5	L.R. 51	UP2338	Sudan
6	L,R. 52	Super Seri # 2	Sudan
7	L.R. 53	KUZ*2/MNV//KAUZ	Egypt
8	L.R. New Valley	Not Available	Egypt
9	L.S. V92	Not Available	Yemen
10	L.S. V99	Not Available	Yemen
11	Sakha 8	G. 155/7C//Inia/3/Nielain	Egypt
12	Sahel 1	CAZO/KAUZ//KAUZ	Egypt

* Source: Plant Genetic Resources Research Department (Bahteem Gene Bank), FCRI, ARC-Egypt.

(2) Yield stability index (YSI) = $\frac{Y_s}{Y_p}$ (Bouslama and Schapaugh, 1984).

(3) $P_i = \sum_{j=1}^{n} \frac{(X_{ij} - M_j)^2}{2n}$ (Clarke *et al.*, 1992).

where *n* is the number of environments, (four environments) *Xij* the grain yield of *i*th genotype in the *j*th environment and *Mj* is the yield of the genotype with maximum yield at location *j*.

(4) $MP = \frac{Y_p + Y_s}{2}$ (Hossain *et al.*, 1990).

(5) TOL = *Y*p – *Y*s (Hossain *et al.*, 1990).

(6) $STI = \frac{Y_p + Y_s}{Y_p^2}$ (Fernandez, 1992).

(7) GMP = (*Y*p × *Y*s)0.5 (Fernandez, 1992).

(8) $\text{Yield index (YI)} = \frac{Y_s}{Y_s}$ (Gavuzzi *et al.*, 1997).

(9) The absolute rank *Di*: = 2 j=1Σn j`=j+1Σn-1{rij-rij`}/n(n-1) (Huhan and Nassar 1989).

where *rij* is the rank yield of *i*th genotype in the *j*th environment.

RESULTS

1. Analysis of variance:

The results of analyses of variance for the studied traits are presented in Table 2. There was a highly significant difference among years for the studied traits except no. of spikelets\spike. The genotypes × years interaction was highly significant, for the studied traits indicating that genotypes performance changed from a year to another. The main effect of moisture regimes was highly significant for the studied traits except for 1000-grain weight where it was significant only. However, the interaction between genotypes × moisture was highly significant for all studied traits. This variation can be explained, in part, by the fact that traits suitable for a given environment with its own weather conditions may be unsuitable in another environment (Austin, 1987 and Van Ginkel *et al.*, 1998).

2- Mean performance of the studied genotypes

L.R. 52 and L.R.53 were the most productive genotypes in irrigated and the least productive ones in non-irrigated conditions. (Table 3). These results suggesting that a high potential yield under optimum condition does not necessarily result in improved yield under stress condition. Thus, indirect selection for a drought-prone environment based on the results of optimum condition may not be efficient. These results are in agreement with those of Ceccarelli and Grando (1991) and Bruckner and Frohberg (1987) who found that landraces of barley and wheat with low yield potential were more productive under stress condition. The lack of response to improved environmental conditions may be related to a lack of adaptation to high-moisture conditions (Clarke *et al.*, 1992). Several studies indicated that semi-dwarf stature is preferred in late season drought condition (Fischer and Maurer, 1978, Richards, 1996 and Van Ginkel *et al.*, 1998). Van Ginkel *et al.* (1998) also found that many grains/spike was critical to high yield only in irrigated condition and it was negatively correlated with yield under late season drought condition.

Plant height data in (Table 3) show that the behavior of all genotypes was the same under irrigated and non irrigated conditions, where the L.R. V 92 was the tallest one. However, the percentage of plant height reduction under non-irrigated condition ranged from 5.22 % to 27.75%. These results were confirmed with those of Mardeh *et al.* (2006).

For spike length, the percentage of reduction under non-irrigated was weak except for L.R. 39 and L.R. 40. On the other hand, for no. of spikelets/spike the percentage of reduction under the non-irrigated condition ranged from 0.56 % to 10.11 %, suggesting that the effect of non irrigated conditions was weak for spike length and no. of spikelets/ spike.

Data in Table 3 also showed that lines numbers. 43, 51, 52 and 53 gave the highest value for no. of spikes/m2. However, these lines exhibit the same trend for grain yield in ton/ha, the percentage of yield reduction under non-irrigated condition ranged from 28.11 % to 47.72%

Table (2): Mean squares for studied traits of 12 bread wheat genotypes evaluated across 4 environments.

S.O.V.	d.f.	Mean square					
		Plant height	Spike length	Spikelets\ spike	No. of spikes/m2	1000-grain weight	Grain yield ton ha-1
Year (y)	1	16539.19**	61.88**	4.08	406653.90**	9320.10**	119.46**
Error	6	108.16	2.29	3.19	198446.00	310.73	0.68
Moisture (m)	1	4840.08**	254.38**	295.02**	1019446.94**	124.07 *	107.18**
M × Y	1	0.01	3.79 *	0.01	16326.22	6.604	2.03 *
genotypes (G)	11	923.26**	29.15**	23.33**	52169.28**	538.29**	5.95**
G × Y	11	138.81**	13.09**	4.71**	34873.80**	538.18**	6.76**
G × M	11	87.21**	4.55**	3.823 *	12620.77	41.61 *	0.86 *
G × M × Y	11	100.97**	3.50**	2.90	10500.42	54.67**	2.10**
Error	138	20.32	0.79	1.81	7371.20	22.947	0.41
CV %		5.05	8.32	6.34	14.77	21.04	18.42

* $p < 0.05$. ** $p < 0.01$.

3- Drought resistance indices

Resistance indices were calculated on the basis of grain yield of genotypes over the years (Table 4). Susceptibility index (SSI) as outlined by Fisher and Maurer (1978) sugges-ted that the genotypes having susceptibility index more than unity means that these geno-types are sensitive and unstable in different environments. By contrast, the genotypes which exhibited SSI less than unity means that these genotypes are more tolerant to drought conditions. The results in Table 4 indicated that all genotypes were tolerant. Genotypes wadi, L.R. 39 and L.R. 42 were the most tolerant over all genotypes. Winter *et al.* (1988) also reported that tall wheat cultivars had a lower SSI. On the other hand, Table 4 represents the values and rankings orders for resistance indices of the 12 genotypes, according to the different resistance indices. Spearman's coefficient of rank correlation (Steel and Torrie, 1980) was then determined for each of the possible pair-wise comparisons of the ranks of the different resistance indices (Table 5). Susceptibility index (SSI) was only significant and positively correlated ($P < 0.05$) with tolerance (TOL). However, SSI was highly significantly and negative with yield stability index (YSI)($r = -1.00$).This indicates that these two procedures were equivalent for ranking purposes which corresponded with previous findings (Mardeh *et al.*, 2006).

Table (3): Mean performance of studied traits evaluated across 4 environments.

Genotype	Plant height (cm)			Spike length (cm)			No. of spikelets/spikes			No. of spikes/m^2			1000- Grain weight			Grain yield ton ha^{-1}		
	IR	NIR	Y.R. (%)a	IR	NIR	Y.R. (%)a	IR	NIR	Y.R. (%)a	IR	NIR	Y.R. (%)a	IR	NIR	Y.R. (%)a	IR	NIR	Y.R. (%)a
L.R. 39	104.38	82.50	20.96	15.00	11.19	25.41	21.63	21.38	1.16	467.50	345.06	26.19	41.99	17.21	59.01	4.35	2.78	36.17
L.R. 40	90.13	71.88	20.25	15.00	9.94	33.75	20.38	20.25	0.61	550.00	373.75	32.05	29.63	18.43	37.82	3.95	2.47	37.56
L.R. 42	91.00	65.75	27.75	10.75	10.38	3.44	20.75	20.75	0.00	570.00	419.41	26.42	25.54	16.39	35.82	3.62	2.29	36.73
L.R. 43	98.63	86.75	12.04	11.25	11.25	0.00	22.25	22.13	0.56	664.17	443.81	33.18	21.05	12.70	39.69	3.66	2.14	41.50
L.R. 51	102.13	76.25	25.34	9.88	9.00	8.91	23.75	23.50	1.05	676.67	475.83	29.68	19.94	13.67	31.43	4.15	2.27	45.26
L.R. 52	89.38	67.88	24.06	9.94	9.50	4.43	22.25	20.00	10.11	640.42	483.33	24.53	15.53	12.74	17.99	3.02	1.62	46.52
L.R. 53	99.38	79.88	19.62	13.38	11.19	16.35	23.88	22.50	5.76	596.67	420.83	29.47	16.03	15.48	3.43	3.39	1.90	43.91
L.R. New Vally	97.75	76.88	21.36	11.88	10.31	13.15	20.50	20.50	0.00	594.58	516.67	13.10	32.32	16.43	49.16	4.31	3.10	28.11
L.R. V92	110.63	97.75	11.64	9.38	8.56	8.66	21.50	20.38	5.21	541.67	403.75	25.46	52.63	10.52	80.02	5.26	2.81	46.53
L.R. V99	100.50	95.25	5.22	10.38	9.25	10.84	21.38	19.75	7.60	435.00	395.17	9.16	32.49	17.50	46.12	4.06	2.39	41.26
Sakha 8	100.63	80.50	20.00	9.50	9.25	2.63	19.88	19.25	3.17	634.17	427.26	32.63	39.78	16.61	58.25	5.45	2.85	47.72
Sahel 1	97.25	77.75	20.05	10.88	9.88	9.20	21.75	20.25	6.90	579.58	496.73	14.30	30.45	21.38	29.77	5.43	3.11	42.73
Mean	98.48	79.92	19.02	11.43	9.97	11.40	21.66	20.89	3.51	579.20	433.47	24.68	29.78	15.75	40.71	4.22	2.48	41.33
LSD (5%)	4.45			0.88			1.33			84.88			4.74			0.63		

LSD: least significant difference at 5% level of significance

Y.R. %: a Percentage of yield reduction under non-irrigated condition.

Table (4): Drought resistance indices and their ranking orders of twelve bread wheat genotypes evaluated across 4 environments.

Genotypes	SSI	Rank	YSI	Rank	*P*	Rank	MP	Rank	TOL	Rank	STI	Rank	GMP	Rank	YI	Rank	Di	Rank
L.R. 39	0.13	10.5	0.64	2	1.68	8	3.56	5	1.57	6	0.40	5	3.47	5	1.12	5	1.33	6.5
L.R. 40	0.14	9	0.62	4	2.35	5	3.21	7.5	1.49	8.5	0.36	7	3.12	6	1.00	6	1.50	4.5
L.R. 42	0.13	10.5	0.63	3	3.40	3	2.96	9	1.33	11	0.33	9.5	2.88	9	0.93	8	1.67	3
L.R. 43	0.15	7.5	0.58	6	3.04	4	2.90	10	1.52	7	0.33	9.5	2.80	10	0.86	10	1.50	4.5
L.R. 51	0.16	5	0.55	9	1.86	7	3.21	7.5	1.88	4	0.36	7	3.07	8	0.92	9	0.83	9.5
L.R. 52	0.17	1	0.53	10.5	4.84	1	2.32	12	1.41	10	0.26	12	2.21	12	0.65	12	0.50	11.5
L.R. 53	0.16	5	0.56	8	3.91	2	2.65	11	1.49	8.5	0.30	11	2.54	11	0.77	11	1.00	8
L.R. New Vally	0.10	12	0.72	1	1.17	9	3.71	4	1.21	12	0.42	4	3.66	4	1.25	2	3.17	1
L.R. V92	0.17	1	0.53	10.5	0.81	10	4.03	3	2.45	2	0.45	3	3.84	3	1.13	4	1.83	2
L.R. V99	0.15	7.5	0.59	5	1.89	6	3.22	6	1.68	5	0.36	7	3.11	7	0.96	7	0.83	9.5
Sakha 8	0.17	1	0.52	12	0.31	12	4.15	2	2.60	1	0.47	2	3.94	2	1.15	3	1.33	6.5
Sahel 1	0.16	5	0.57	7	0.52	11	4.27	1	2.32	3	0.48	1	4.11	1	1.26	1	0.50	11.5

Yield stability index (YSI) was calculated for the twelve genotypes (Table 4). Genotypes L.R. New Valley, L.R. 39, L.R. 42 and L.R. 40 had the lowest yield under non-irrigated conditions, but they had the greatest yield stability. However, Sahel 1 L.R. V92, L.R. 52 and L.R. 53 had the largest difference between grain yield under irrigated and non irrigated conditions, and hence the lowest yield stability index. YSI was significantly correlated with tolerance (TOL). None of the other resistance index with the YSI. This indicates that these two procedures were equivalent for ranking purposes which corresponded with previous findings (Bouslama and Schapaugh, 1984).

Data in Table 4 also showed the values of superiority measurement (Pi) . In this regards Huhan and Nassar (1989) and Lin and Binns (1988) reported that the tested genotypes, which had low values (nearly zero or zero) are considered as high tolerant to drought. Sakha 8, Sahel 1 and L.R. V92 had the lowest values for Pi. However, Pi was highly significantly correlated ($P < 0.01$), and negative in magnitude with mean productivity (MP), stress tolerance index (STI), geometric mean productivity (GMP), and yield index (YI), while with tolerance (TOL) the relation was significantly negative ($P < 0.05$). Similar results were obtained by Mardeh *et al.* (2006). However, Lin *et al.* (1986) used *P* for differentiating stress resistance genotypes, but it did not seem to be useful under severe stress conditions.

Mean productivity (MP) and yield tolerance (TOL) were calculated for all 12 genotypes to identify those that had desirable high MP or low tolerance values. Genotypes with high MP included Sahel 1, Sakha 8, L.R. V92 and L.R. New Valley. Sahel 1, Sakha 8, and L.R. V92 performed well because of high yields under non- irrigated conditions (Table 3). MP is mean production under both stress and non-stress conditions (Rosielle and Hamblin, 1981), it will not be correlated with yield under stress. For this reason, MP was not able to differentiate cultivars belonging to a certain group from the others. As described by Hohls (2001) selection for MP should increase yield in both stress and non-stress environments unless the correlation between yield in contrasting environments is highly negative. The MP can be related to yield under stress only when stress is not too severe and the difference between yield under stress and non-stress conditions is not too much and cultivars with a high MP would belong to group A in these situations

Genotypes with the best tolerance values (L.R. New Valley, L.R. 42, L.R. 52 and L.R. 53) were generally lower yielding in irrigated conditions. However, both MP and TOL were significantly and positively correlated to each other, and also both were significantly and positively correlated with geometric mean productivity (GMP Similar results were reported by Clarke *et al.* (1992) and Rosielle and Hamblin (1981). Rizza *et al.* (2004), however, showed that a selection based on minimum yield decrease under stress with respect to favorable conditions (TOL) failed to identify the best genotypes.

Stress tolerance index (STI) and geometric mean productivity (GMP) were calculated for all 12 genotypes to identify those that had desirable high STI and GMP values as outlined by Fernandez (1992). Generally, both measures had a highly significant positive correlation between them. Also, they had the same rank for the studied genotypes. According to these measures, genotypes Sahel1, Sakha 8, L.R. V92, L.R. New Valley and L.R. 39 were high tolerant to drought. There was highly significance and positive correlation between these two measures (STI and GMP) and yield index (YI) by r = 0.94** and r = 0.97** respectively.

YI, as proposed by Gavuzzi *et al.* (1997) ranks cultivars only on the basis of their yield under stress. YSI, as Bouslama and Schapaugh (1984) stated, evaluates the yield under stress of a cultivar relative to its non-stress yield, and should be an indicator of drought resistant genetic materials. So, the cultivars with a high YSI are expected to have high yield under both stress and non-stress conditions. In the present study, however, genotypes (Sahel 1, L.R. New Valley, Sakha

8, L.R. V92 and L.R. 39) with the highest YSI exhibited the lowest yield under non irrigated conditions and the high yield under stress conditions (Table 3).

Data in Table 4 showed the values of absolute rank (Di). In this regards, Huhan and Nassar (1989) and Lin and Binns (1988) reported that the tested genotypes, which had low values (nearly zero or zero) are considered as high tolerant to drought. Sahel 1 L.R. 52, L.R. V92 and L.R. 51 had the lowest values for Di. However, there was not a significant correlation between either Di. and other resistance indices.

Table (5): Spearman's rank correlation for all the resistance indices

Resistance indices	YSI	*P*	MP	TOL	STI	GMP	YI	Di
SSI	-1.00	-0.23	-0.02	0.57 *	0.00	-0.05	-0.24	-0.54
YSI		0.12	-0.01	-0.60*	-0.02	0.01	0.20	0.42
P			-0.97**	-0.68*	-0.97**	-0.96**	-0.90**	-0.14
MP				0.62*	0.99**	0.99**	0.96**	0.15
TOL					0.63 *	0.58 *	0.38	-0.27
STI						0.99**	0.95**	0.17
GMP							0.97**	0.20
YI								0.29

* $p < 0.05$. ** $p < 0.01$.

DISCUSSION

Two schools of thought have been announcement to answer the question that should breeding do selection under both potential and stress conditions or on selection in either environment alone? The first of these philosophies believe in selection under favorable condition (Richards, 1996, Van Ginkel *et al.*, 1998, Rajaram and Van Ginkle, 2001 and Betran *et al.*, 2003). The breeders who advocate selection in favorable environments follow this philosophy. Producers, therefore, prefer cultivars that produce high yields when water is not so limiting but suffer minimum loss during droughty seasons (Nasir Ud-Din *et al.*, 1992 and Mardeh *et al.*, 2006). The second thought belief in selection in the prevailing conditions found in target environments (Ceccarelli, 1987, Ceccarelli and Grando, 1991 and Rathjen, 1994). Several researchers have concluded that selection will be most effective when the experiments are done under both favorable and stress conditions (Fischer and Maurer, 1978, Clarke *et al.*, 1992, Nasir Ud-Din *et al.*, 1992, Fernandez, 1992, Byrne *et al.*, 1995 and Rajaram and Van Ginkle, 2001). Trethowan *et al.* (2002) showed that selection in alternating drought and non-drought environments at the International Maize and Wheat Improvement Center (CIMMYT) has resulted in a significant progress in the development of wheat germplasm adapted to dry areas globally.

When breeding for drought resistance is the aim, two situations seem to be clearly distinguished in order to choose a selection strategy: (1) where the drought condition is predominant over the years and wet years are infrequent, and (2) where the drought condition happens rarely and wet years are predominant. In the regions with the former situation, selection should be based on the yield in the target environments as suggested by Ceccarelli (1987), Ceccarelli and Grando, 1991 and Rathjen (1994). The latter situation exists (e.g. most parts of Europe), selection in favorable environments will be more effective because input responsiveness, so important in the wetter, admittedly less frequent, but much more productive years can be easily maintainned in the germplasm (Richards, 1996, Van Ginkel *et al.*, 1998, Rajaram and Van Ginkel, 2001 and Betran *et al.*, 2003).

CONCLUSIONS

If the strategy of breeding program is to improve yield in non-stress environment, it may be possible to explain local adaptation to increase gains from selection conducted directly in that environment (Atlin *et al.*, 2000 and Hohls, 2001). However, selection should be based on the resistance indices calculated from the yield under both conditions, when the breeder is looking for the cultivars adapted for a wide range of environments.

The findings of this study showed that the breeders should pay attention to genotypes L.R. V92, L.R. New Valley, and L.R. 39. These genotypes should be involved in breeding program for developing new tolerant varieties to drought. The use of different concepts of selection indices will lead to different rankings of genotypes. However, superiority measure (*Pi*) mean productivity (MP), stress tolerance index (STI), geometric mean productivity (GMP) and yield index (YI) are suggested to differentiate genotypes for drought resistance.

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تقييم أدلة المقاومة للجفاف في قمح الخبز تحت الظروف المروية وغير المروية

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تهدف الدراسة الى تقييم قدرة عدة ادلة انتخاب للتعرف على التراكيب الوراثية المقاومة للجفاف تحت ظروف بيئية مختلفة. حيث تمت زراعة ١٢ تركيب وراثى من قمح الخبز مختلف فى محصول الحبوب فى تجارب منفصلة تحت الظروف المروية وغير المروية بمحطة البحوث والتجارب الزراعية بكلية الزراعة - جامعة القاهرة خلال موسمى ٢٠٠٦/٢٠٠٧ و٢٠٠٧/٢٠٠٨. تم استخدام ٩ من ادلة الانتخاب اشتملت على دليل الحساسية للجفاف (SSI) ودليل ثبات المحصول (YSI) ومقياس التفوق (Pi) ومتوسط الإنتاجية (MP) والتحمل (TOL) ودليل التحمل للجفاف (STI) والمتوسط الهندسى للإنتاجية (GMP) ودليل المحصول (YI) والترتيب المطلق (Di) .

أظهرت النتائج ان *P*i, MP, STI, GMP, YI كانت الافضل فى التعرف على التراكيب الوراثية ذات المحصول العالى تحت الظروف المرويه وغير المرويه. وبشكل عام يؤدى استخدام ادلة انتخاب مختلفة الى الحصول على ترتيب مختلف للتراكيب المستخدمة لذا على مربى النبات ان يأخذ شدة الاجهاد في الاعتبار عند اختيار ادلة الانتخاب المناسبة.