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STABILITY STATISTICS OF SOME FABA BEAN GENOTYPES BY

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ABSTRACT

To develop high yielding varieties with improved level of resistance to biotic and a biotic stresses under different agroclimatic conditions (North Delta, Middle and Upper Egypt) and to develop cultivars which can be adapted to a wide range of diverse environment, this study aimed to evaluate and explore the reliability of some stability statistics methods namely: phenotypic stability of Eberhart and Russell (1966), genotypic stability of Tai (1971), stability variance of Shukla (1972) and Wricke (1962) and yield stability statistic of Kang and Magari (1995).

Three groups of faba bean genetic resources were used in the study: Group I (North Delta): Six genotypes were planted at three locations (Nubaria, Etaai El-Barood and Tag Elez Research Stations); group II (South Delta and Middle Egypt): Five genotypes were sown at three sites (Seds, Sers El-Liaan and El-Gemmiza Research Stations) and group III (Upper Egypt): Six genetic resources were grown at two locations (El-Matana and Kom Ombo Research Stations). At each location, the experiment was conducted during the three successive seasons of 2003/04, 2004/05 and 2005/06 in randomized complete block design with four replications.

Group I (North Delta), genotypes: 1556/914/2001, 943/1151/93 and 1426/711/2000 exhibited phenotypic stability (Eberhart and Russell method). Genotypic stability (Tai's method) results showed that genotypes 1556/914/2001 and 1426/711/2000 exhibited an above and below average degrees of stability, respectively. Concerning stability-variance of Shukla, the genotypes 1195/901/99, 1233/848/99 and 1426/711/2000 were stable. Using coefficient of Ecovalence (contribution of each genotype in genotype x environment interaction), it was clear that genotype 1233/848/99 scored the lowest value followed by 1195/961/99, 943/1151/93 and 1426/711/2000 indicating stability differences among faba bean genotypes over environments. The Kang and Magari method showed clearly that 4 genotypes out of 6 exhibited yield stability of high performance.

Group II (South Delta and Middle Egypt): Genotypes: 1046/1130/97, 1532/464/2001, and 1534/476/2001 were of stable yield according to parameters of Eberhart and Russell while genotypes: 1532/464/2001 and 1534/476/2001 scored below and above average degrees of genotypic stability. With regard to stability-variance method of Shukla, results showed that only genotype 1164/535/99 was stable. According to Wi index of Wricke the lowest genotype of contribution in interaction with environment was genotype 1046/1130/97 and followed by 1534/476/2001 showing stability differences among faba bean genotypes over environments. Genotypes: 1046/1130/97, 1532/464/2001 and 1534/476/2001 were characterized by yield stability of high performance according to Kang and Magari method.

Group III (Upper Egypt): Genotypes: 943/1159/93, 1436/435/2000 and 1016/733/95 were phenotypically stable of yield where they met assumptions of Eberhart and Russell. According to Tai's parameters, the genotypes: 943/1159/93 and 1436/435/2000 cleared an above average degree of genotypic stability. Average degree of stability was obtained by genotype: 1419/936/99 and below average degree was cleared by genotype 917/824/93. Shukla's method results showed that genotypes Misr 1, 917/824/93, 1419/936/99, 943/1159/93 and 1436/435/2000 have stable yield. According to Wi index of Wricke the lowest contribution of each genotype in interaction was obtained by genotypes 1419/936/99 followed by genotypes 943/1159/93 and 917/824/93 indicating stability differences among faba bean genotypes over environments. Using stability statistic (YSi) of Kang and Magari, the genotypes 1016/733/95, 1419/936/99, 943/1159/93 and 1436/435/2000 had stability of high performance for faba bean yield.

The results of the three groups revealed that genotype 1233/848/99 at North Delta, genotypes 1046/1130/97 and 1534/476/2001 at South Delta and Middle Egypt and genotypes 943/1159/93 and 1436/435/2000 at Upper Egypt were of stable genotypes using the studied stability methods. Therefore, the above mentioned genotypes could be recommended to be as commercial stable of high yielding cultivars and/or incorporated to be as breading stocks in any future breading program aiming for producing high yielding lines for seed yield of faba bean.

Key words: Faba bean, Vicia faba L., Environments, Stability statistics.

INTRODUCTION

Faba bean (*Vicia faba* L.) is one of the most important leguminous crops in Egypt. Research activities were more directed to develop high yielding varieties with improved level of resistance to biotic and a biotic stresses under different agroclimatic conditions (North Delta, Middle and Upper Egypt). The average cultivated area devoted to faba bean represented around 200,000 feddan during 2003/04, 2004/05 and 2005/06 growing seasons with average seed yield of 9.2 ardab/feddan. About 85% of the total area is located in North Delta, where foliar diseases prevailed and severely attacked the crop with an average of 39.7% yield losses, particularly during wet seasons (Mohamed, 1982). Heavy infestation with parasitic weed broomrape *(Orobanche Crenata)* is currently a major constrant of faba bean production in Middle and Upper Egypt and caused serious damage.

The development of cultivars or varieties, which can be adapted to a wide range of diverse environment, is the ultimate goal of plant breeders in a crop improvement program. Genotype x environment interaction is of major importance for the faba bean breeder because phenotypic response to a change in the environment is different among genotypes. Several techniques have been proposed to characterize the stability of yield performance when the genotypes are tested at a number of environments. Allard and Bradshaw (1964) discussed the relationship between genotype x environment interaction. Eberhart and Russell (1966) reported that regression of the mean performance of a genotype on an environmental index and the deviation from regression are two parameters to measure phenotypic stability of the tested genotypes. Another statistical procedure was described by Tai (1971) who suggested partitioning the genotype x environment interaction into two components namely: α statistic that measures the linear response to environmental effects and λ that measures the deviation from linear response in terms of magnitude of error variance.

Several studies were carried out to estimate stability parameters to compare the genotypes of leguminous crops. Lai *et al.* (1974) in soybean genotypes found that estimation of deviation from regression gives an idea as to how much reliance should be given to linear regression in the interpretation of the data. Nguyen *et al.* (1980) cleared that genotypic stability was inversely proportional to ecovalence (Wi). Nassib *et al.* (1986) noticed highly significant interaction between genotypes and environments in Middle Egypt region in their studies on faba bean genotypes. Genotype x environment interaction and deviation from the linear response were studied by Abo El-Zahab *et al.* (1986) for estimating the genotypic stability of genotypes in soybean. Omar *et al.* (1999) cleared that combined analysis revealed significance of pooled deviation of genotypes, environment and its interaction. El-Hosary *et al.*, (2006) in their study on faba bean, reported that genotype, environment and genotype x environment interaction mean squares were highly significant.

The methods that provide a stability-variance parameter assignable to each genotype should be useful to the breeders. Shukla (1972) developed an unbiased estimate of stability variance of the *ith* genotype (σi^2) and also a criterion for testing the significance of σi^2 to determine whether or not a genotype was stable. The stability-variance method has been evaluated by Eagles and Frey (1977) to select oat (*Avena sativa*) cultivars. This method can be extended to use a covariate to remove its linear effect from GE interaction. The remainder variance of GE interaction can be assigned to each genotype (S_i^2) and the significance of each tested component, (Kang and Miller, 1984). Recently, Kang and Magari (1995) depending only on Shukla (1972) proposed an integrated yield and stability of performance statistic (YS*i*) for simultaneous selection for yield and stability. The influence of the genotype x environment interaction in the phenotypic performance has been reported by Redden *et al.* (2000) and Truberg and Hühn (2000). They reported that plant breeding is not carried out only to obtain high yield capacity in the genotypes, but also requires productive performance stability over many environmental conditions. Corte *et al.* (2002) concluded that the estimates of the coefficients of genetic variation and environmental variation showed the presence of genetic variability among the cultivars and lines assessed. They also reported that adaptability and phenotypic stability estimates showed that there was generally wide adaptability and stable performance of the cultivars and lines in the environments.

The current study aimed to explore the reliability of some stability statistics for evaluating seventeen faba bean genotypes grown in different environments.

MATERIALS AND METHODS

Three groups of faba bean genetic resources were used in this study. Group I (North Delta): Six genotypes *i.e.*, Giza 716, 943/1151/93, 1195/961/99, 1233/848/99, 1426/711/2000 and 1556/914/2001 were planted in the first two weeks of November at three locations (Nubaria, Etaai El-Barood and Tag Elez Research Stations).

Group II (South Delta and Middle Egypt): Five genotypes *i.e.*, Misr 1, 1164/535/99, 1046/1130/97, 1532/464/2001, and 1534/476/2001 were sown at the last week of October at three sites (Seds, Sers El-Liaan and El-Gemmiza Agricultural Research Stations).

Group III (Upper Egypt): Six genetic resources *i.e.*, Misr 1, 917/824/93, 1016/733/95, 1419/936/99, 943/1159/93 and 1436/435/2000 were grown in the last two weeks of October at two locations (El-Matana and Kom Ombo Research Stations).

At each location the experiment was conducted during three successive seasons of 2003/04, 2004/05 and 2005/06 in randomized complete block design with four replications. Each experimental plot consisted of six ridges, 60 cm apart and 3 meters long ($10.8m^2$). Planting took place on two rows per ridge, in double seeded hills, 25 cm apart. Cultural practices were done as recommended for faba bean packages.

Code number and pedigrees of all tested genotypes are presented in Table 1. At harvest, three central ridges of each plot ($5.4m^2$) were threshing to estimate seed yield (Ard/fed).

Statistical analyses

1. Analysis of variance

Regular analysis of variance of RCBD as outlined by Gomez and Gomez (1984) was applied on each individual environment. Bartelett's test of homogeneity was adopted indicating no statistical evidence for heterogeneity. Thus combined analysis of variance for the three experiments was done as follows: First experiment, included six genotypes over three locations (nine environments). Second experiment, six genotypes over two locations (six environments). Third experiment, included five genotypes over three locations (nine environments). Genotypes and environments were considered as fixed and random variables, respectively. Least significance difference test (LSD) was used to detect differences between genotypes over all the studied environments.

Confidence intervals (C.I.) were calculated to compare between each genotype mean and the grand mean of all genotypes over all environments.

Table (1): Code number, name and pedigrees of the studied faba bean genotypes for group I (North Delta), group II (South Delta and Middle Egypt) and group III (Upper Egypt).

Cod No.	Name	Pedigree
Group I		
1	Giza 716	Giza 716
2	943/1151/93	Giza3 x 461/A837/83
3	1195/961/99	990/1530/90/899/614/89
4	1233/848/99	985/1415/90 x 900/668/89
5	1426/711/2000	S40/93 x Giza blanka
6	1556/914/2001	S40/93 x T.W.
Group II		
1	Misr 1	Misr 1
2	1164/535/99	00616 x 899/501/89
3	1046/1130/97	A123/45/76 x Giza 461
4	1532/464/2001	(ICARDA/2544/86 x T.W.) x (ICARDA/2544/86 x S40/93)
5	1534/4761/2001	S40/93 x T.W.
Group III		
1	Misr 1	Misr 1
2	917/824/93	Giza2 x 461/A837/83
3	1016/733/95	716/724/88 x 30/18/72
4	1419/936/99	Seliem (S.M.L.) x A123/45/76
5	943/1159/93	Giza 3 x 461/A837/83
6	1436/435/2000	ICARDA/2544/86 x Giza 716

2- Stability analysis

Four stability methods namely: phenotypic (Eberhart and Russell (1966), genotypic (Tai 1971), stability-variance (Shukla 1972) and Wricke (1962) and yield stability statistic (Kang and Magari 1995) were conducted for differentiating the studied faba bean genotypes. Also, to use the available information from these estimates for obtaining stable genotypes to be released as experimental lines to be incorporated in a breeding program for stable high yielding potential cultivars.

2.1. Phenotypic stability

In the analysis of phenotypic stability of Eberhart and Russell (1966), the performance of individual genotype is regressed on an environmental index (deviation of the mean yield at that environment from the overall mean yield of all environments). The analysis provides the linear regression coefficient, b, (performance response index) and the deviation from regression mean square, S^2d, (stability index).

2.2. Genotypic stability

Concerning genotypic stability, genotype x environment interaction effect was partitioned into two statistics which were estimated for each genotype separately. The first statistic is α_i that measures the linear response to environmental effects and the second is λ_i that measures deviation from linear response in terms of magnitude of the error variance.

Genotypes of perfect stability would not change its performance from one environment to another. This is equivalent to stating that $\alpha = -1$ and $\lambda = 1$ because perfectly stable genotypes probably do not exist. Plant breeders will have to be satisfied with the obtainable levels of stability *i.e* average stability ($\alpha = 0$ and $\lambda = 1$), whereas the values ($\alpha > 0$ and $\lambda = 1$) will be as below average stability, however, the values ($\alpha < 0$ and $\lambda = 1$) will be referred as above average stability.

2.3. Stability-variance of Shukla (1972) and Wricke (1962):

Stability-variance was determined separately by calculating unbiased estimators of σ_i^2 (heterogeneity) and S^2_i (deviation variance) before and after considering the linear effect of environmental index, respectively. To remove the effect of the environmental index, GE interaction sum of squares was divided into two components: heterogeneity due to linear effect of environmental index (measured as environment mean yield minus overall mean yield) and the residual or deviation variance components. Also, Shukla used the index Wi, Coefficient of Ecovalence, (Wricke, 1962) index of stability that represent the proportion of genotype x environment interaction (G x E) some of squares attributed to each genotype.

2.4. Yield-stability method

The yield–stability statistic (YS*i*) method which developed by Kang and Magari (1995) depending on Shukla (1972) was used. In this method the degree of stability of higher performance via two statistics *i.e* σ_i^2 and Y_i that were confounded into one measure called YS*i*. The various steps used in calculating the YS*i* statistic for the *ith* genotype are as follows: (i) determine the contribution of each genotype to GE interaction by calculating σ_i^2; (ii) assign ranks to genotypes from highest to lowest yield, with the lowest yield receiving the rank of 1; (iii) calculate protected LSD for mean yield comparisons; (iv) adjust yield rank according to LSD; (v) determine significance of σ_i^2 using an approximate F-test; (vi) assign stability rating as follows: -8, -4 and –2 for σ^2 significant at 0.01, 0.05 and 0.1 probability levels, respectively and zero for insignificant σ^2 (The higher the σ^2 the less stable the genotype); (vii) sum adjusted yield rank and stability rating for each genotype to determine YS*i* statistic. (viii) Calculate mean YS*i* and identifies genotypes with YS*i* greater than mean YS*i* to be characterized by stability of high performance *i.e* stable and high yielding.

RESULTS AND DISCUSSION

Faba bean yield character was analyzed using combined analysis of variance and regression analysis, results are presented in Table 2. Mean squares of genotypes were highly significant for the first group. In the second group, highly significant environment (linear) mean squares were found indicating that environments differ in their effect to different genotypes when tested with pooled deviation. Insignificant genotype x environment (linear) mean squares was found indicating that genotypes did not differ genetically in their response to different environments when tested with pooled deviation. On the other hand, the highly significant pooled deviation was cleared indicated that faba bean genotypes significantly differed regarding the deviation from their respective average linear response. In the third group, mean squares of environments and genotype x environments interaction was highly significant indicating that genotypes considerably varied across different environments. Environment + (genotype x environment) interaction was partitioned into environment (linear), genotype x environment (linear) interaction (Sum of squares due to regression, bi) and unexplained deviation from regression (Pooled deviation mean squares, S^2d) for the three groups. Highly significant mean squares due to Giza 716, 1195/961/99, 1233/848/99 and 1556/914/2001 genotypes and Misr 1, 917/824/93, 1016/733/95, 1419/936/99 and 943/1159/93 genotypes were found in the first and third groups, respectively. On the other hand, significant mean squares due to genotyps Misr 1 and 1046/1130/97 in the second group.

With respect to analysis of variance for stability-variance of Shukla's and Kang's methods, results in Table 3 cleared highly significant mean squares due to genotypes (G), environments and genotypes x environments interaction, respectively, in the three experiments indicating that genotypes considerably varied across different environments. Partitioning the GE interaction revealed that heterogeneity caused by the environmental index was insignificant for all experiments.

The significant residual of all groups cleared that the non-linear components were also significant. Lai *et al.* (1974), Nassib *et al.* (1986), Abo El-Zahab *et al.* (1986), Omar *et al.* (1999), Redden *et al.* (2000), Truberg and Hühn (2000) and El-Hosary *et al.*, (2006) who found that non-linear components were significant in their studies.

Therefore, it could be concluded that it is essential to determine the stability degree for each genotype. Results of each experiment will be discussed for the stability methods separately.

Group I (North Delta).

Results of stability parameters using different stability methods for yield of six faba bean genotypes grown in Nubaria, Etaai El-Barood and Tag Elez for three years are presented in Table 4. The results clearly indicated that yield was significantly affected by genotypes. The highest yield/fed was given by genotype 1426/711/2000 being 14.699 ard/fed followed by genotypes 943/1151/93 and 1556/914/2001 that produced 12.958 and 11.183 ard/fed, respectively. On the other hand, the lowest yield/fed was given by genotypes Giza 716, 1195/961/99 and 1233/848/99 recording 10.623, 10.968 and 10.904 ard/fed, respectively.

The results of phenotypic stability (Eberhart and Russell method) indicated that the value of regression coefficient did not significantly differ from unity (b = 1) for the studied genotypes. Also, values of deviation from regression (S^2d) were not significantly different from zero ($S^2d = 0$) for genotypes 943/1151/93, 1233/848/99, 1426/711/2000 and 1556/914/2001. Actually b measures the reaction of the genotype to the environmental effects, then it is considered as a parameter of response, while S^2d exhibits the degree of stability. Mean performance of yield for genotypes 943/1151/93 and 1426/711/2000 were significantly greater than that of all genotypes. It is evident that these genotypes had regression coefficient and deviation from regression did not significantly differ from one and zero, respectively. Moreover, it had mean performance significantly greater than the mean of all genotypes. Therefore, genotypes 943/1151/93 and 1426/711/2000 met al.l the stability characteristics of the stable genotypes as described by Eberhart and Russell (1966) and could be recommended as a stable genotype for faba bean yield. These results are similar to those obtained by Lai *et al.* (1974), Nassib *et al.* (1986), Abo El-Zahab *et al.* (1986), Omar *et al.* (1999), Redden *et al.* (2000) and Truberg and Hühn (2000) who reported that adaptability and phenotypic stability estimates showed that there was generally wide adaptability and stable performance of the cultivars and lines in the environments.

Table (2): Combined analysis for faba bean yield character of the studied genotypes for the three experiments according to Eberhart and Russell (1966) method.

Sources	DF	Mean Squares
Group I (North Delta)		
Total	53	7.066
Genotypes (G)	5	23.321
Env + (G x Env.)	48	5.374
Environment Linear)	1	124.127
G X Env. (Linear)	5	3.1279
Poold Deviation	42	2.8137
Giza 716	7	3.185
Giza3 x 461/A837/83	7	1.119
990/1530/90/899/614/89	7	3.075
985/1415/90 x 900/668/89	7	3.378
S40/93 x Giza blanka	7	1.2068
S40/93 x T.W.	7	4.918
Pooled error	162	0.6969
Group II (South Delta and Middle Egypt)		
TOTAL	44	6.988
Genotypes (G)	4	0.381
Env + (G x Env.)	40	7.647
Environment Linear)	1	133.11
G X Env. (Linear)	4	3.622
Poold Deviation	35	4.524
Messr 1	7	3.975
00616 x 899/501/89	7	4.171
A123/45/76 x Giza 461	7	6.911
(Icarda/2544/86 x T.W.) x (Icarda/2544/86 x S40/93)	7	4.500**
S40/93 x T.W.	7	3.062
Pooled error	135	0.249
Group III (Upper Egypt)		
Total	35	6.558
Genotypes (G)	5	0.836
Env + (G x Env.)	30	7.512
Environment Linear)	1	207.01
G X Env. (Linear)	5	1.186
Poold Deviation	24	0.517
Messr 1	4	0.964
Giza2 x 461/A837/83	4	0.383
716/724/88 x 30/18/72	4	0.922
Seliem (S.M.L.) x A123/45/76	4	0.413
Giza 3 x 461/A837/83	4	0.122
Icarda/2544/86 x Giza 716	4	0.296
Pooled error	108	0.385

Table (3): Analysis of variance of faba bean yield for the three experiments according to Shukla's stability variance and Kang's methods.

Sources	Group I (North Delta)		Group II (South Delta and Middle Egypt)		Group III (Upper Egypt)	
	DF	Mean squares	DF	Mean squares	DF	Mean squares
Total	53	-	44	-	35	-
Genotypes (G)	5	13001.8^{**}	4	9100^{**}	5	3700.4^{**}
Environments	8	92.026^{**}	8	100.02^{**}	5	146.6^{**}
G. X Env.	40	3098.6^{**}	32	2248^{**}	25	1473.28^{**}
Heterogeneity	5	24739.84^{**}	4	17877^{**}	5	7350.174^{**}
Residual	35	6.994087^{**}	28	15.197^{**}	20	10.5563^{**}
Pooled error	135	2.9282	108	0.975	90	1.2705

With regard to genotypic stability (Tai's method), the results in Table 6 and Fig 1 showed that genotype 1426/711/2000 and 1556/914/2001 exhibited below and above average degrees of stability, respectively. The distribution of α statistic for genotype 1426/711/2000 was negative and significantly differed from zero suggesting that this genotype was responsive to poor environment. The distribution of λ statistic indicates that it was greater than unity for genotypes Giza 716, 943/1151/93, 1195/961/99 and 1233/848/99 (Fig 1) indicating the importance of the unpredictable component of GE interaction and these genotypes were of unstable yield. These findings are in agreement with those reported by Omar *et al.* (1999) who cleared significance of pooled deviation of genotypes, environment and its interaction.

Concerning stability-variance of Shukla (1972), examining values of $\sigma i2$, (heterogeneity) displayed in Table 4, cleared that genotypes 1195/961/99, 1233/848/99 and 1426/711/2000 were stable where they had insignificant values of $\sigma i2$ and S2 (deviation variance). Genotypes Giza 716, 943/1151/93 and 1556/914/2001 were unstable since they had significant values of $\sigma i2$. After linear effect of the environmental index (a covariate) was removed and S2 values were examined, the above mentioned 3 genotypes continued to be considered unstable.

The genotype stability is inversely proportional to Wi index (Coefficient of ecovalence), Wricke (1962). This index of stability represents the proportion of genotypic x environment interaction (G x E) sum of squares attributed to each genotype. The values of Wi index in Table 4 cleared that genotype 1233/848/99 scored the lowest value followed by 943/1151/93, 1195/961/99 and 1426/711/2000 indicating stability differences among faba bean genotypes over environments. On the other hand, the highest contribution of genotypes in genotype x environment interaction, Wi, was obtained by, genotypes 716 and 1556/914/2001 indicating more response to the environmental change, (Table 4). These results are similar to those obtained by Nguyen *et al.* (1980) who cleared that genotypic stability was inversely proportional to ecovalence (Wi).

Necessary statistics for evaluating faba bean genotypes using YSi stability for yield according to Kang and Magari (1995) are presented in Table 4. The results clearly indicating that 4 genotypes out of 6 showed stability of high performance for yield. They had YSi value greater than the YSimean. Genotypes Giza 716 and 943/1151/93 had values of YSi less than the mean YSi, so they were declared unstable for faba bean yield.

Group II (South Delta and Middle Egypt).

Table 5 represents the results of stability measurements for faba bean yield using different stability methods to evaluate 5 genotypes grown at Seds, Sers El-Liaan and El-Gemmiza for three years. The results clearly showed that yield was significantly affected by genotypes. However, genotype 1046/1130/97 gave the highest value for yield (11.03 ard/fed) and the lowest yield was given by genotype 1164/535/99 being 10.513 ard/fed.

Results of phenotypic stability showed that the regression coefficients were not significantly different from unity for all genotypes. Deviation from regression (S^2d) values did not significantly differ from zero for genotypes 1046/1130/97, 1532/464/2001, and 1534/476/2001. On the other hand, values of regression coefficient significantly differed from zero (b=0) for genotypes Misr 1, 1046/1130/97, 1532/464/2001, and 1534/476/2001 and these genotypes had yield greater than the mean of all genotypes. Therefore genotypes 1046/1130/97, 1532/464/2001, and 1534/476/2001 were of phenotypically stable yield where they met assumptions of Eberhart and Russell (1966) for stable genotypes. The results were similar to those of Nassib *et al.* (1986), Abo El-Zahab *et al.* (1986), Omar *et al.* (1999), Redden *et al.* (2000) and Truberg and Hühn (2000) who reported that adaptability and phenotypic stability estimates showed that there was generally wide adaptability and stable performance of the cultivars and lines in the environments.

Results in Table 5 and Fig 3, according to Tai's parameters, cleared that genotype 1534/476/2001 scored above average degree of stability ($\alpha < 0$ and $\lambda = 1$) and genotype 1532/464/2001 cleared below average degree of stability ($\alpha > 0$ and $\lambda = 1$). On the other hand, genotypes Misr 1, 1164/535/99 and 1046/1130/97 were unstable. The obtained results are similar to those reported by Omar *et al.* (1999) who cleared significance of pooled deviation of genotypes, environment and its interaction.

With regard to stability-variance method of Shukla (1972), results in Table 5 showed that genotype 1164/535/99 was judged to be unstable where its values of both σ_i^2 and S^2 were significant. When values of S^2 were examined, after taking the linear effect of the covariate (heterogeneity) into account genotype 1164/535/99 became to be a stable yield.

Results of ecovalence according to Wi index of Wricke (1962) indicating the contribution of genotype in interaction (genotype x environment), showed that the lowest values were obtained by genotypes 1046/1130/97 and 1534/476/2001 indicating that they were poor responsive to the environmental change. These results indicated stability differences among faba bean genotypes over environments. On the other hand, the highest values of Ecovalence were obtained by genotypes Misr 1, 1164/535/99, 1532/464/2001 and 1534/476/2001 indicating that they were more responsive to the environmental change (Table 5). These results are similar to those obtained by Nguyen *et al.* (1980) who cleared that genotypic stability was inversely proportional to ecovalence (Wi).

Genotypes 1046/1130/97, 1532/464/2001, and 1534/476/2001 were characterized by yield stability of high performance according to Kang and Magari method as shown in Table 5. These genotypes had YSi values greater than the mean YSi. On the other hand, genotypes Misr 1 and 1164/535/99 had values of YSi less than the mean YSi. Therefore, these genotypes were judged to be unstable, (Table 5).

Group III (Upper Egypt).

The results of the four stability methods regarding faba bean yield of six genotypes grown at El-Matana and Kom Ombo for three years are shown in Table 6. Faba bean genotypes significantly affected yield. Genotype 943/1159/93 gave the highest value recording 12.796 ard/fed, and genotype 1436/435/2000 ranked the second (12.346 ard/fed) followed by genotypes 1016/733/95 (12.161ard/fed) and 917/824/93 (11.958 ard/fed). The lowest yield was obtained by genotypes 1419/936/99 (11.866 ard/fed) and Misr 1 (11.798 ard/fed).

Results of phenotypic stability presented in Table 6 showed that the value of regression coefficient did not significantly differ from unity (b=1) for the studied genotypes. Values of deviation from regression S^2d were not significantly different from zero. Genotypes 1016/733/95, 943/1159/93 and 1436/435/2000 had significantly greater yield than the mean of all genotypes. It was observed from the results that genotypes 1016/733/95, 943/1159/93 and 1436/435/2000 were phenotypically stable for yield where they met assumptions of Eberhart and Russell (1966) for stable genotypes. These results are similar to those obtained by Nassib *et al.* (1986), Abo El-Zahab *et al.* (1986), Omar *et al.* (1999), Redden *et al.* (2000) and Truberg and Hühn (2000) who reported that adaptability and phenotypic stability estimates showed that there was generally wide adaptability and stable performance of the cultivars and lines in the environments.

According to Tai's parameters, results in Table 6 and Fig 3 cleared that an above average degree of genotypic stability was shown by genotypes 943/1159/93 and 1436/435/2000 ($\alpha < 0$ and $\lambda = 1$) and an average degree of genotypic stability was obtained by genotype 1419/936/99 ($\alpha = 0$ and $\lambda = 1$). Below average degree of genotypic stability was cleared by genotype 917/824/93 ($\alpha > 0$ and $\lambda = 1$). The distribution of α statistic for genotypes 943/1159/93 and 1436/435/2000 was negative and significantly differed from zero suggesting that this genotype was responsive to poor environment. Genotypes Misr 1 and 1016/733/95 were out of range of Tai's parameters indicating that they were more responsive to the environmental change and, in turn they were considered unstable genotypes. The results were similar to those of Omar *et al.* (1999) who cleared significance of pooled deviation of genotypes, environment and its interaction.

Table (4): Mean performance and Eberhart and Russell, Tai's, Shukla's and Kang and Magari stability measurements for yield of six faba bean genotypes over nine environments of group I (North Delta).

Genotypes	Eberhart and Russell parameter (Phenotypic stability)					Tai's parameter (Genotypic stability)				Shukla's parameter and Wi ecovalence of (Wricke. 1962)			Kang & Magari's parameter		
						α_{vi}	λ_{vi}	Stability degree							
	Means	b_{vi}	S^2d_{vi}	$T_{bvi}=0$	$T_{bvi}=1$			95%	99%	Sigma-square	S-square	Wi	Adjusted	Stability Rating	YS (I)
Giza 716	10.623	0.594	2.487**	1.514	-1.955	-0.420	4.543			7358.9**	8.873**	43380	-2	-8	-10
943/1151/93	12.958*	1.362	0.4225	5.855**	1.556	0.374	1.586			2208.5**	-1.128	15911	-1	-8	-9
1195/961/99	10.968	1.036	2.378**	2.687*	0.093	0.037	4.410			-387.562	5.777	2065	0	0	0 +
1233/848/99	10.904	.593	1.681	2.467*	-1.007	-0.421	4.821			-479.202	8.798	1577	7	0	7 +
1426/711/2000	14.699**	0.885	0.510	3.665*	-.476	-0.118	1.729	+	+	2456.2	9.172	17232	8	-8	0 +
1556/914/2001	11.183	1.529	1.221	3.136*	1.085	0.547	0.712	+++	+++	7440.6**	10.471**	43816	9	-8	1 +

L.S.D. for genotypes = 0.968 and 1.272 at 5% and 1%, respectively. + Below average stability.
* Confidence Interval. (5%) 10.921 < 11.889 < 12.857 + + Average stability.
** Confidence Interval. (1%) 10.617 < 11.889 < 13.161 +++ Above average stability

Table (5): Mean performance and Eberhart and Russell, Tai's, Shukla's and Kang and Magari stability measurements for yield of five faba bean genotypes over nine environments of group II (South Delta and Middle Egypt).

Genotypes	Eberhart and Russell parameter					Tai's parameter				Shukla's parameter and Wi ecovalence of (Wricke. 1962)			Kang & Magari's parameter		
						α_{vi}	λ_{vi}	Stability degree							
	Means	b_{vi}	S^2d_{vi}	$T_{bvi}=0$	$T_{bvi}=1$			95%	99%	Sigma-square	S-square	Wi	Adjusted	Stability Rating	YS (I)
Misr 1	10.959	1.184	3.726**	3.064*	0.476	0.1871	10.803			5599.5**	23.41**	30474	-2	-8	-10
1164/535/99	10.513	0.869	3.921**	2.169	-0.131	-0.1336	2.712			657.37**	7.25	6752	-1	-8	-9
1046/1130/97	11.030*	0.529	2.062	2.638*	-0.924	-0.4784	3.950			-729.6	12.43**	95.11	0	0	0 +
1532/464/2001	10.955	1.513	2.210	3.680*	1.247	0.5211	2.1188	++	++	881.05**	11.02**	7826	7	-8	-1 +
1534/476/2001	10.904	0.905	2.012	2.668*	-0.280	-0.0962	1.732			4833.3**	21.86**	2697	8	-8	0 +

L.S.D. for genotypes = 0.133 and 0.175 at 5% and 1%, respectively. + Below average stability.
* Confidence Interval. (5%) 10.739 < 10.872 < 11.005 + + Average stability.
** Confidence Interval. (1%) 10.697 < 10.872 < 11.047 + + + Above average stability.

Table (6): Mean performance and Eberhart and Russell, Tai`s, Shukla`s and Kang and Magari stability measurements for yield of six faba bean genotypes over six environments of group III (Upper Egypt).

Genotypes	Eberhart and Russell parameter					Tai`s parameter				Shukla`s parameter and Wi ecovalence of (Wricke, 1962)			Kang & Magari`s parameter		
						α_{vi}	λ_{vi}	Stability degree							
	Means	b_{vi}	S^2d_{vi}	$T_{bvi}=0$	$T_{bvi}=1$			95%	99%	Sigma-square	S-square	Wi	Adjusted	Stability Rating	YS (I)
Misr 1	11.798	1.261	0.578	1.106	0.228	0.2658	2.8827			3587.5**	-0.2108	13185.2	-2	-8	-10
917/824/93	11.958	1.157	-0.003	0.730	0.099	0.1602	1.1465	+	+	1033.1**	3.0271	4670.61	-1	-8	-9
1016/733/95	12.161	0.948	0.537	3.429*	-0.188	-0.0534	2.7879			-204.6	3.8909*	544.65	0	0	0 +
1419/936/99	11.866	1.001	0.027	-4.178	-0.569	0.0012	1.2496	++	++	-205.6	1.3464	541.27	7	0	7 +
943/1159/93	12.796*	0.750	-0.263	3.045*	-1.015	-0.2544	0.3395	+++	+++	1020.2**	1.6031	4627.78	8	-8	0 +
1436/435/2000	12.346	0.883	-0.089	0.457	-0.605	-0.1194	0.8894	+++	+++	3602.1**	-0.3185	13233.9	9	-8	1 +

L.S.D. for genotypes = 0.637 and 0.838 at 5% and 1%, respectively.

* Confidence Interval. (5%) 11.517 < 12.154 < 12.791

** Confidence Interval. (1%) 11.316 < 12.154 < 12.992

\+ Below average stability.

\+ + Average stability.

\+ + + Above average stability.

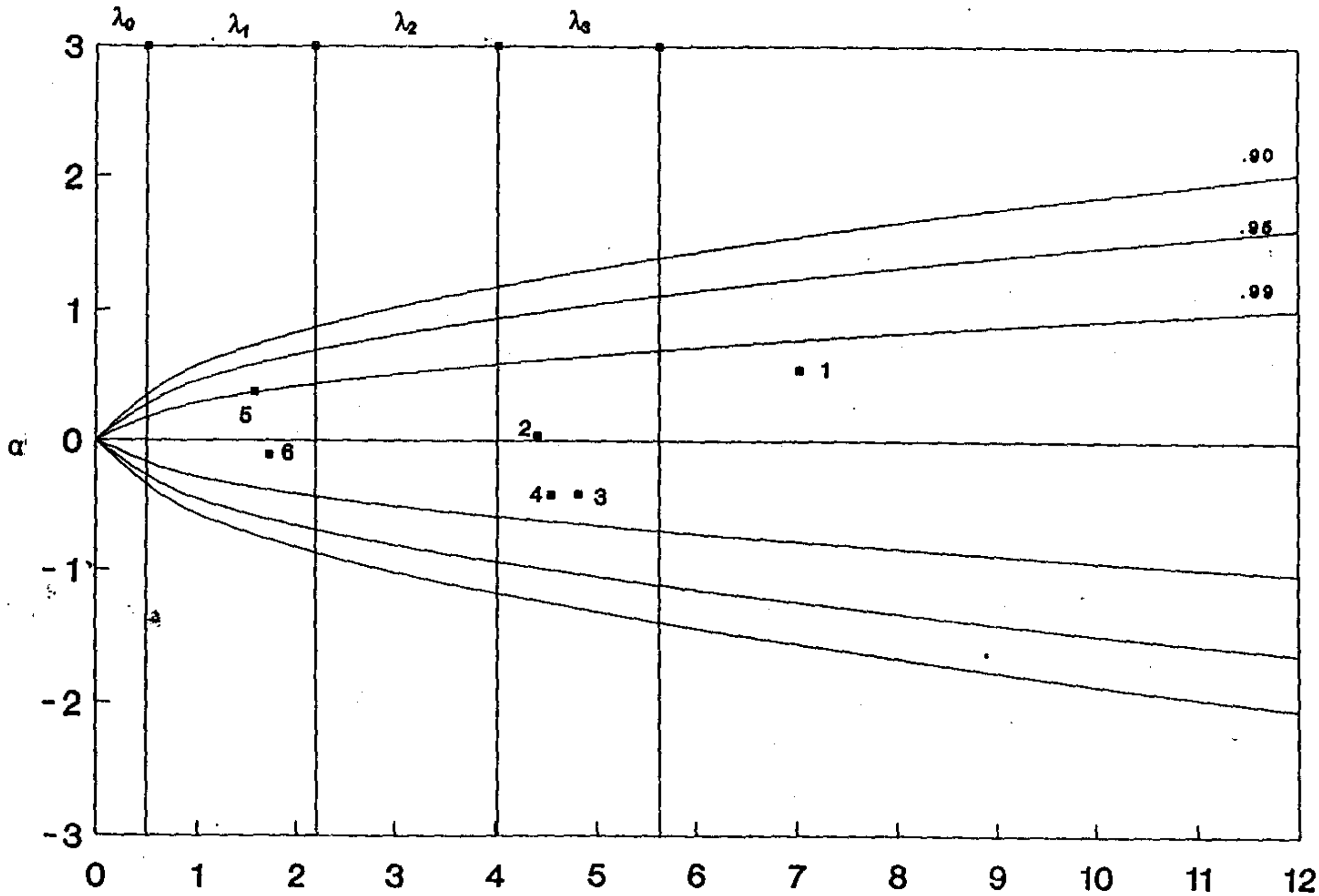

Fig.1: Stability dstribution for group I.

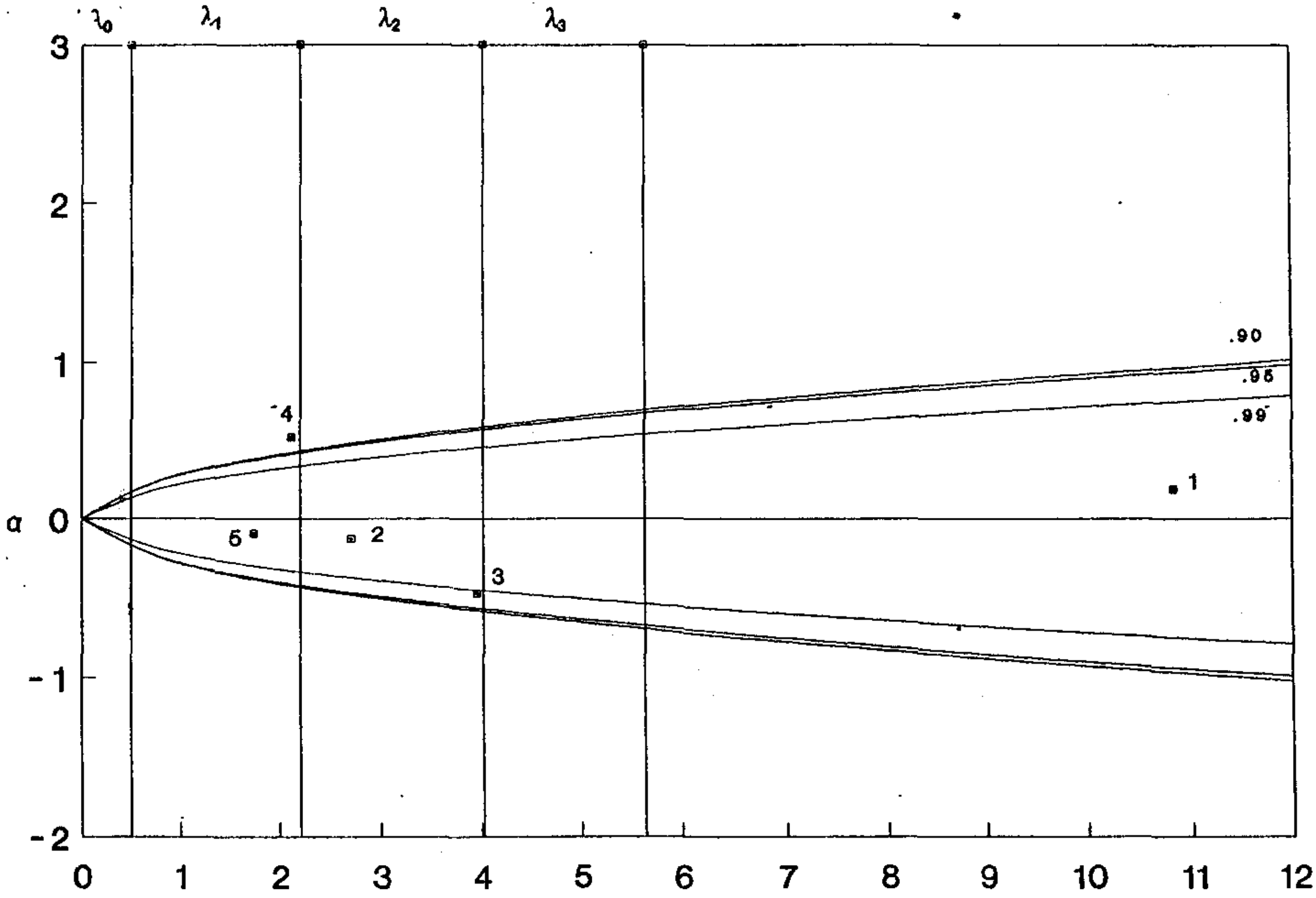

Fig.2: Stability distribution for group II.

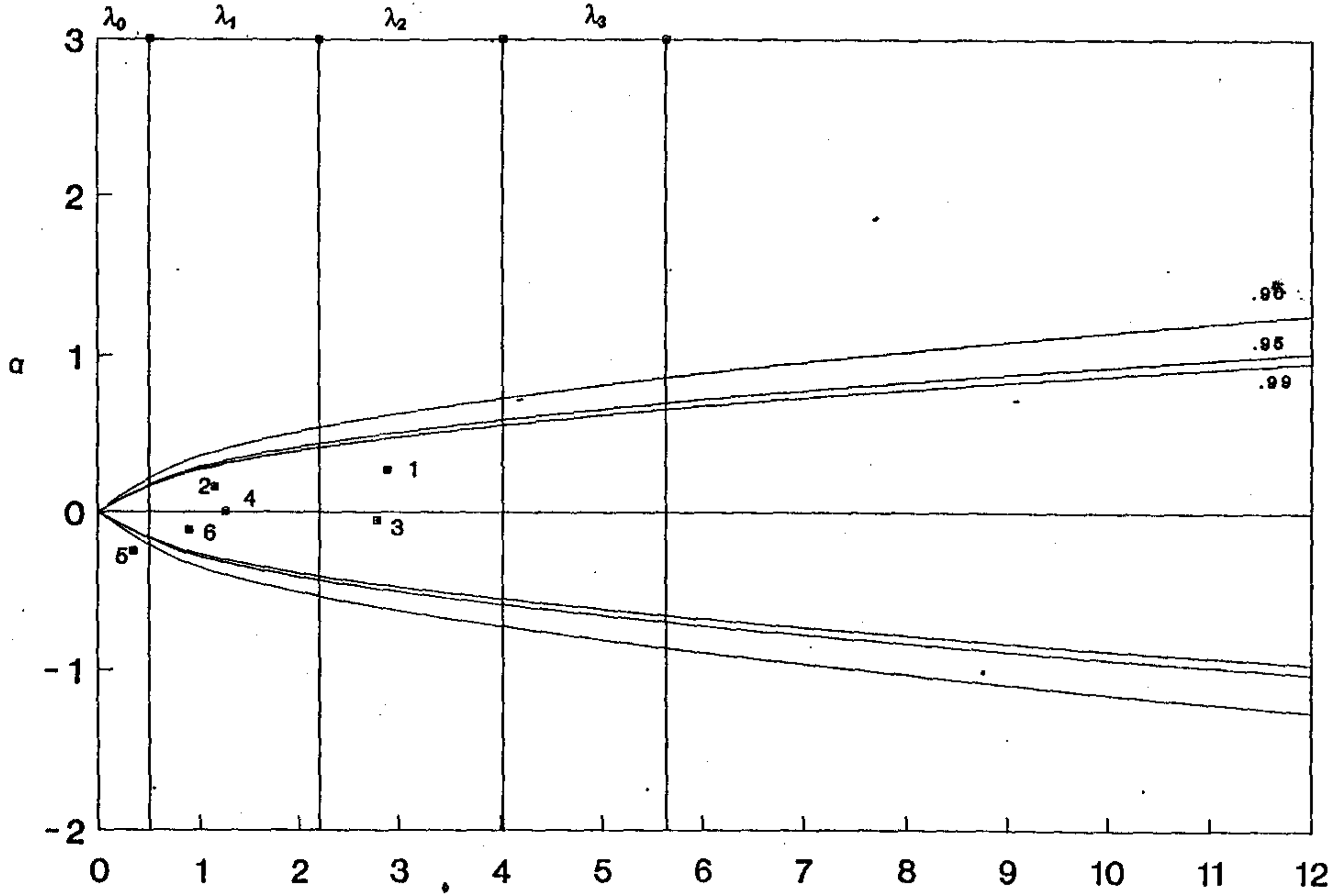

Fig.3: Stability distribution for group III.

Concerning stability-variance method of Shukla (1972), results in Table 6 showed that genotypes Misr 1, 917/824/93, 943/1159/93 and 1436/435/2000 were judged to be unstable where their values of both σ_i^2 and S^2 were significant. When values of S^2 were examined, after taking the linear effect of the covariate into account (heterogeneity), the genotypes Misr 1, 917/824/93, 1419/936/99, 943/1159/93 and 1436/435/2000 became to be of stable yield. According to Wi index of Wricke (1962) the lowest contribution of each genotype in genotype x environment interaction was obtained by, genotypes 1016/733/95 and 1419/936/99 followed by genotypes 917/824/93 and 943/1159/93 indicating that they were poor responsive to the environmental change. These results indicated stability differences among faba bean genotypes over environments. On the other hand, the highest contribution in genotype x environment interaction (Ecovalence) was obtained by genotypes Misr 1 and 1436/435/2000 indicating that they were more responsive to the environmental change. So they were considered unstable genotypes, (Table 6). These results are similar to those obtained by Nguyen *et al.* (1980) who cleared that genotypic stability was inversely proportional to ecovalence (Wi).

Data of yield stability (YSi) calculated as outlined by Kang and Magari (1995) presented in Table 6 showed that genotypes 1016/733/95, 1419/936/99, 943/1159/93 and 1436/435/2000 had values of YSi greater than the mean YSi indicating stability of high performance for faba bean yield. On the other hand, genotypes Misr 1 and 917/824/93 were declared unstable for seed yield where their values of YSi were less than the mean YSi.

Generally, results of group I (North Delta), group II (South Delta and Middle Egypt) and group III (Upper Egypt), revealed that genotype 1233/848/99 at North Delta, genotypes 1046/1130/97 and 1534/476/2001 at South Delta and Middle Egypt and genotypes 943/1159/93 and 1436/435/2000 at Upper Egypt were of stable genotypes using the studied stability methods. Therefore, the above mentioned genotypes could be recommended to be as commercial stable of high yielding cultivars and/or incorporated to be as breading stocks in any future breading program aiming for producing high yielding lines for seed yield of faba bean.

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احصائيات الثبات لبعض التراكيب الوراثية من الفول البلدى

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** المعمل المركزى لبحوث التصميم والتحليل الاحصائى – مركز البحوث الزراعية.

للحفاظ على المحصولية العالية للاصناف وتحسين مستوى مقاومتها الحيوية وتحملها لظرف التقسية المناخية والبيئية المختلفة ولتحسين التراكيب الوراثية التى من الممكن ان تتأقلم مع ظروف مناخية على نطاق واسع اجريت هذه الدراسة فى ثلاثة مناطق رئيسية لزراعة الفول البلدى هى المنطقة الاولى شمال الدلتا والمنطقة الثانية جنوب الدلتا ومصر الوسطى والمنطقة الثالثة هى مصر العليا وذلك بتقييم التراكيب الوراثية المستخدمة من حيث ثباتها الوراثى والمفاضلة بينها باستخدام المعالم الوراثية لبعض طرق حساب الثبات الوراثى للوصول الى درجة عالية من الدقة للحكم على ثبات التركيب من عدمه وذلك بعدة طرق ذات الدلالة المختلفة على هذا الثبات هى طريقة Eberhart and Russell (1966) لحساب الثبات المظهرى وطريقة Tai (1971) لحساب الثبات الوراثى وطريقة Shukla (1972) and Wricke (1962) لحساب الثبات على أساس التباين وطريقة Kang and Magari (1995) لحساب معالم Kang والمعدلة لطريقة Shukla وذلك بهدف استخدام المعلومات المتاحة من هذه التقديرات لتوجيه برامج التربية

ولتحقيق كل ما سبق تم زراعة ثلاثة مجموعات من التراكيب الوراثية للفول البلدى المجموعة الاولى (شمال الدلتا) واشتملت على ستة تراكيب وراثية زرعت فى النصف الاول من نوفمبر فى ثلاث مناطق هى النوبارية وايتاى البارود وتاج العز والمجموعة الثانية (جنوب الدلتا ومصر الوسطى) واشتملت على خمسة تراكيب وراثية زرعت فى الاسبوع الاخير من اكتوبر والاسبوع الاول من نوفمبر فى ثلاث مناطق هى سدس وسرس الليان والجميزة والمجموعة الثالثة (مصر العليا): واشتملت على ستة تراكيب وراثية زرعت فى النصف الثانى من اكتوبر فى منطقتين هما المطاعنة وكوم امبو. وقد تم اجراء كل تجربة من التجارب السابقة فى كل منطقة ثلاث سنوات متتالية هى ٢٠٠٣/٢٠٠٤ ، ٢٠٠٤/٢٠٠٥ ، ٢٠٠٥/٢٠٠٦ فى تصميم القطاعات الكاملة العشوائية فى اربع مكررات حيث اشتملت كل من المجموعة الاولى والثانية على ٩ بيئات واشتملت المجموعة الثالثة على ٦ بيئات وكانت مساحة القطعة التجريبية ١٠,٨ م^{٢} مشتملة على ٦ خطوط وتم تطبيق كل التوصيات الخاصة بمحصول الفول البلدى وعند تمام النضج تم تقدير صفة المحصول من الخطوط الثلاث الداخلية لكل قطعة بالاردب / فدان وقد لخصت النتائج كما يلى:

المجموعة الاولى (شمال الدلتا):

حققت التراكيب الوراثية 943/1151/93 ,1556/914/2001، 1426/711/2000 **ثباتا مظهريا بطريقة** (Eberhart and Russell) **وقد حققت التراكيب الوراثية**

1556/914/2001 ، 1426/711/2000 ثباتا وراثيا اعلى واقل من المتوسط على الترتيب وذلك بطريقة (Tai`s) واما بطريقة (1972) Shukla فقد اظهرت ثبات التراكيب الوراثية 1195/961/99، 1233/848/99 ، 1426/711/2000 وباستخدام معامل Wricke (1962) Coefficient of Ecovalence حقق التركيب الوراثى 1233/848/99 اقل قيمة ثم تبعه التراكيب 1195/961/99 ، 943/1151/93 ، 1426/711/2000 مشيرا الى اختلاف درجة الثبات لهذه التراكيب عبر البيئات المختلفة واما بطريقة Kang and Magari فقد اظهرت ثبات وراثيا فى المحصول لاربعة اصناف من الستة المختبرة.

المجموعة الثانية (جنوب الدلتا ومصر الوسطى):

وقد حققت التراكيب الوراثية 1046/1130/97 ، 1532/464/2001 ، 1534/476/2001 ثباتا مظهريا بطريقة (Eberhart and Russell) وقد حقق التركيبان الوراثيان 1532/464/2001 ، 1534/476/2001 ثباتا وراثيا اقل واعلى من المتوسط على الترتيب وذلك بطريقة (Tai`s) واما بطريقة ثبات التباين (1972) Shukla فقد اظهر التركيب الوراثي 1164/535/99 وحده ثباتا وراثيا وباستخدام معامل (Wricke 1962) Coefficient of Ecovalence حقق التركيب الوراثي 1534/476/2001 اقل قيمة مشيرا الى عدم تأثره بالاختلافات البيئية وشدة ثباته واما بطريقة Kang and Magar فقد أظهرت ثبات وراثيا فى المحصول لثلاثة تراكيب وراثية هى 1046/1130/97 ، 1532/464/2001 ، 1534/476/2001 الخمسة المختبرة فى هذه المجموعة.

المجموعة الثالثة (مصر العليا):

وقد حققت التراكيب الوراثية 943/1159/93 ,1436/435/2000، 1016/733/90 ثباتا مظهريا بطريقة (Eberhart and Russell) وقد حقق التركيبان الوراثيان 943/1159/93 ، 1436/435/2000 ثباتا وراثيا اعلى من المتوسط والتركيب 1419/936/99 ثباتا متوسطا والتركيب 917/824/93 ثباتا اقل من المتوسط وذلك بطريقة (Tai`s) واما بطريقة (1972) Shukla فقد اظهرت ثبات التراكيب الوراثية Misr 1 ، 917/824/93 ، 1419/936/99 ، 943/1159/93 ، 1436/435/2000 وباستخدام معامل (Wricke 1962) coefficient of Ecovalence حقق التركيب الوراثى 1016/733/95 ، 1419/936/99 ، 943/1159/93 ، 917/824/93 اقل قيمة على الترتيب مشيرا الى اختلاف درجة الثبات لهذه التراكيب عبر البيئات المختلفة باستخدام طريقة Kang and Magar فقد اظهرت ثباتا وراثيا فى المحصول للتراكيب 1016/733/95 ، 1419/936/99 ، 943/1159/93 ، 1436/435/2000

وبصفة عامة يمكن القول بان التركيب الوراثى 1233/848/99 اظهر ثباتا وراثيا ومظهريا فى مناطق شمال الدلتا ومثله التركيبان الوراثيان 1046/1130/97 ، 1534/476/2001 فى مناطق جنوب الدلتا ومصر الوسطى وايضا التركيبان الوراثيان 943/1159/93 ، 1436/435/2000 فى مناطق مصر العليا وعلى ذلك ينصح باستعمال هذه التراكيب الوراثية فى برامج التربية كأصول وراثية تتمتع بالقدرة المحصوليه ودرجة الثبات المرتفعه.