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Influence of Drought on Yield and Yield Components in White Bean

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***Abstract*—**In order to study seed yield and seed yield components in bean under reduced irrigation condition and assessment drought tolerance of genotypes, 15 lines of White beans were evaluated in two separate RCB design with 3 replications under stress and non stress conditions. Analysis of variance showed that there were significant differences among varieties in terms of traits under study, indicating the existence of genetic variation among varieties. The results indicate that drought stress reduced seed yield, number of seed per plant, biological yield and number of pod in White been. In non stress condition, yield was highly correlated with the biological yield, whereas in stress condition it was highly correlated with harvest index. Results of stepwise regression showed that, selection can we done based on, biological yield, harvest index, number of seed per pod, seed length, 100 seed weight. Result of path analysis showed that the highest direct effect, being positive, was related to biological yield in non stress and to harvest index in stress conditions. Factor analysis were accomplished in stress and non-stress condition a, there were 4 factors that explained more than 76 percent of total variations. We used several selection indices such as Stress Susceptibility Index (SSI), Geometric Mean Productivity (GMP), Mean Productivity (MP), Stress Tolerance Index (STI) and Tolerance Index (TOL) to study drought tolerance of genotypes, we found that the best Stress Index for selection tolerance genotypes were STI, GMP and MP were the greatest correlations between these Indices and seed yield under stress and non stress conditions. In classification of genotypes base on phenotypic characteristics, using cluster analysis (UPGMA), all allels classified in 5 separate groups in stress and non stress conditions.

***Keywords*—**Cluster analysis, factor analysis, path analysis, selection index, White bean

I. INTRODUCTION

DROUGHT stress is one of the major causes for crop loss, reducing a average yields with 50% and over [34]-[39]. The Development of bean genotypes that are more resistant to water stress is a practical and economical approach to lessen the negative effects of drought on the productivity of the crops [23]. Bean breeders are most interested in drought resistance.
Drought resistance is defined as relative yield of a genotype compared to other genotypes subjected to the same drought stress [23]-[30]. Soil water deficits that occur during the reproductive growth are considered to have the most adverse effect on crop yield [4]-[10]. Several studies have shown that water deficits imposed during the reproductive development of dry beans can decrease the number of flowers, pods and number of seeds per [5]-[38]. The total number of flowers in some varieties may be reduced up to 47% under drought conditions affecting the number of pods per plant and its reduced in a range between 21 and 65% [22]-[35]. The direct measurement of seed yield is the most practical way to screen for drought resistance [1]-[32]-[37]. Since drought resistance is a quantitatively inherited performance based trait, selection needs to be practiced with advanced generation lines in replicated trials over years and locations [26]-[31]. It is important that breeders have clear assessment of the kind of drought that occurs in a particular production region, since the genotypic response and mechanisms to resist or tolerate drought can differ in beans, because in a region there may be Intermittent drought is due to climatic patterns of sporadic rainfall that causes intervals of drought [26]. It may be terminal drought occurs when plants suffer lack of water during later stages of reproductive growth or when crops are planted at the beginning of a dry season [16]. However, it should be noted that The effect of soil heterogeneity or topography can increase drought stress and contributes to the uneven application of irrigation water [37]. Consequently, breeders choose their tests for drought stress according to climatic conditions, An example in drought screening trials conducted over a three-year period in Palmira [28] provided bean plants with adequate moisture until flowering. After flowering, the water-stress plots received an average of 20 mm of water whereas the control plots received an average of 80 mm of water. Reference [6] shows that selection for earlier flowering, a greater rate of partitioning and a shorter reproductive period permitted the selection of small red bean breeding lines having one week earlier maturity without sacrificing yield potential. Lines with earlier maturity would be less vulnerable to terminal drought, but caution needs to be exercised, as an association between early maturity and lower yields exists. Reference [1]-[23]-[32] stated that drought stress can reduce biomass, number of seeds and pods, days to maturity, harvest index, seed yield, and seed weight in common bean. A moderate drought stress has reduced yield by 41% [15]. Correlation studies and using factor analysis and path analysis as multivariate statistical methods provide the possibility to recognize the most important effective characters on grain yield and also the hidden factors causing correlation between the characters [19]. Reference [11] in the study of morphologic characters and yield components in limited and unlimited growth genotypes, used factor analysis by main components method and factors rotation by varimax method, Analysis of all genotypes indicated three factors that respectively 31.31, 31 and 14.8% and totally 77.1% of the total variation. Reference [7] shows the researchers used the factor analysis method in an investigation on red bean, Kidney bean and white bean, generally there were seven factors that explained 77.8 percent of the total variations. Reference [17] shows the factor analysis method in investigation on 15 lines of the Red bean and generally Factor analysis were accomplished in non stress and water stress conditions There were 5 factors that explained 74 percent in non stress

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condition and 73 percent of total variations in stress condition. Reference [7]-[11]-[20] shows using of the cluster analysis for the bean characters, determination of the genetic variation and geographical distribution. Reference [8] stated that the genotypes with high yield may not tolerate the drought stress and their high yield is just due to their high potential of yield. Reference [18] shows that a resistant variety should be evaluated in stress conditions and then be selected. Several methods for evaluating the reaction of crops against environmental stresses were considered, one of the considered indices is the Stress Susceptibility Index (SSI) that was presented by [14]. The low amount of this index indicates the low susceptibility of the genotype to stress. Reference [24] introduced the Tolerance Index (TOL) as a difference of the yield of stress and non-stress condition and also introduced Mean Productivity (MP) which shows the mean yield of a genotype in both moisture stress and non-stress conditions, genotype with lower TOL and more MP show that the genotype has more tolerance to stress condition. Reference [13] recommended the Stress Tolerance Index (STI) as the stress tolerance in order to identify the high yield genotypes in both stress and non-stress condition. Becoming more amount of this index represents the more tolerance to stress. Fernandez also introduced the Geometric Mean Productivity (GMP), the more amount of this index indicates the more tolerance to stress. Reference [17] in their investigation on bean, [2] on maize hybrids, Reference [21] on wheat, introduced two GMP and STI indices as the best indices separating genotypes with proper yield in both stress and non-stress conditions than other genotypes. Reference [26] shows showed the geometric mean (GM) of seed yield to be the best predictor of bean genotype performance in stress and non-stress environments. They recommended a breeding strategy that involved genotypic selection based first on GM, followed by selection based on seed yield in the stress environment. The purpose of this study is evaluate seed yield and other related characters in white bean under stress and non-stress conditions, determining the best index of drought tolerance and applying them to selection of the best drought tolerated lines.

II. Material and Methods

In this study, 15 lines of White bean from the collection of Khomein Researcher Center in Iran selected:

(1.KH_41118,2.KH_41231,3.KH_41134,4.KH_41114,5.KH_41112,6.KH_41232,7.KH_41102,8.KH_41234,9.KH_41234,10.KH_41119,11.41124,12.KH_41128,13.KH_41126,14.KH_41116,15.KH_41238), was studied and compared.

The land preparation operations consist of autumn plough, spring disk and leveling. Manually sowing operation was performed in in two separate RCB design with 3 replications under stress and non stress conditions. In non stress condition irrigation period was every 7 days and in stress condition was every 12 days (9, 19). Each experimental unit consists of 4 four meter rows, the space between rows was 50cm and the space between the bushes on the row was 10cm. Approximately 50 days after sowing when the bushes have enough growth and the risk of omission of plants due to stress is eliminated, stressing (in water stress treatment) started and continued till the end of growth phase. In the harvest phase, from each experimental unit, five random bushes (by omitting 0.5m from the beginning and the end of the cropping lines as the marginal effect) were harvested completely from the soil and transferred to the laboratory for measurements of other characters. Studied morphological traits height per plant, number of pod, weight of pod, pod length, pod width, number of seed per plant, number of seed per pod, seed length, seed width, seed thickness,100-seed weight, biological yield, seed yield and harvest index. After gathering the respective information, to consider the existence of variety in characters between the studied genotypes and the existence of significant difference between characters, the simple variance analysis was performed on all stress and non stress condition and for every line. To determine the yield components, the Forward stepwise Regression Analysis method was applied, and to determine the direct and indirect effects of characters with high correlations with the yield, the path analysis method was used by which correlation between characters were divided into direct and indirect components and the most suitable characters affecting the yield in stress and non stress conditions were verified. To identify factors affecting the yield, as well as characters grouping, the factors analysis by principal components methods and factors rotation by the varimax method were used. In each main and independent factor, the coefficients more than 0.5 were considered as the significant factors. the biggest factor coefficient in each factor or a set of significant characters in a factor which are morphologically distinguished and important were used to name factors. To evaluate the drought tolerance of the genotypes, different tolerance and susceptibility STI, SSI, MP, TOL, GMP indices for considered line were determined and these lines were classified for susceptibility and tolerance by the use of these indices. The above indices were calculated by these formulas, where Yp is the yield in the non stress conditions, Ys is the yield in the stress conditions, $\bar{Yp}$ is the total mean yield in the without-stress conditions and $\bar{Ys}$ is the total mean yield in the stress conditions.

1- Stress Susceptibility Index (SSI):

$$SSI = (1-Ys/Yp)/ SI \quad (1)$$

$$SI = 1-(\bar{Ys} / \bar{Yp})$$

2- Stress Tolerance Index (STI) and Geometric Mean Productivity (GMP):

$$STI = (Yp)(Ys)/(\bar{Yp})^2$$

$$GMP = \sqrt{(Yp)(Ys)} \quad (13)$$

3- Tolerance Index (TOL) and Mean productivity (MP):

$$TOL = Yp - Ys \quad (2)$$

$$MP = (Yp + Ys)/2$$

In order to determine the most proper indices for distinguishing the lines and genotypes resistant to stress, simple correlation between yield in stress and non stress conditions and different indices were calculated and those indices which in both conditions had relatively high correlation with the yield were selected as the best indices. For grouping the studied samples to determine the variety between different genotypes and determination of their distance and nearness, the cluster analysis was performed by the use of Unweighted Paired Group Method using arithmetic (UPGMA).

Simple variance analyzed statistical calculations were performed using SAS software, stepwise regression analysis, factor analysis and cluster analysis were performed applying MINITAB and MSTAT-C, and calculation of drought tolerant indices were performed by Excel software.

III. Results and Discussion

A. Variance Analysis Results:

It indicates that there is a very significant difference between the lines which expresses the genetic variety between the lines.

B. Study the Effects of Drought on the Measured Characters in 15 Lines of the Beans:

According to (TABLE I) the most damage due to drought stress was related to the seed yield (61%). Reference [7]-[17]-[23]-[31] shows the most stress effect on the seed yield. It is concluded that this damage is due to drastic decline in characters including a decrease in the number of seed (57.9%), weight of pod (56%), the biological yield (47.8%), the number of pods (38%) and number of seed per pod (33.4%). Reference [23] shows that among the yield components, the number of pods and the number of seeds in per plant have more decrease due to stress. Meanwhile, the number of pod (54%) comparing to the number of seed per pod (44%) was more affected by the stress. The decrease in the grain yield in stress condition is mainly due to a decline in the number of pods in each plant [5]-[31]. Meanwhile, Reference [5]-[16]-[17]-[22]-[31]-[38] shows that the number of pod comparing to the number of seed per pod has more susceptibility. The least effect of stress on the characters was observed in the seed length (2.03%). Reference [23] shows that in the stress conditions, the seed size is the most constant component. Reference [17] shows the least effect of stress on the seed length (2.4%). Reference [16]-[17]-[23]-[38] shows that among the various characters, changing in the seed size in the stress conditions was less reported. These results are similar to other researchers' results, As Reference [5] shows in their survey on the bean in the stress conditions, obtained the decrease percentage of yield 60.2, the number of seeds per pod 28.9, the harvest index 25.7 and the seed weight 22.3. Meanwhile, obviously, none of the characters presents a positive reaction to the stress.

TABLE I
Characters Mean and Percent Reduction of Characters in 15 Lines of White Bean

characters	character mean		Percent Reduction
	non-stress	stress	
Height	72/90	71/05	40579
number of pods	39/78	24/34	38
Pod weight	20/08	27973	56
Pod length	32721	34516	40822
Pod width	36039	15220	40671
number of seeds per pod	19784	12816	33/4
number of seeds per plant	139/44	65/48	57/9
Seed length	25873	17107	40577
Seed width	40734	28642	17258
Seed thickness	21337	19115	16
100-seed weight	29/93	24/16	19/3
Seed yield	35/36	13/70	61
Biological yield	75/06	39/18	47/8
Harvest index	0/46	0/342	26

C. The Results of Simple Correlation:

Simple correlation between the characters in 15 lines of bean in the stress and non-stress conditions was calculated. Referring to the correlation matrix in the non-stress conditions (TABLE II), it is observed that seed yield has a positive, significant correlation with the biological yield (0.841), the harvest index (0.793), the number of seeds per plant (0.786), the number of seeds per pod (0.599), the number of pods (0.435), height (0.360) and the pod length (0.320) characters, respectively. Reference [25] shows reported that the correlation of the seed yield with the number of pods per plant is positive and significant. 100-seeds weight and the seed size characters had a negative relationship with the number of pods, number of seed per pod, and the number of seed per plant, this explains that by increasing the number of pods, the number of seed per pod and the number of seed per plant will decrease the seed size and 100-seeds weight. Also Reference [27] shows that 100-seeds weight has a negative correlation with two yield components the number of pod and the number of seed per plant. In characters correlation studies, it was observed that 100-seeds weight has a positive and very significant correlation with the seed width and thickness characters, indicating that the seed weight criterion can be used in the measurements instead of the seed width and thickness in the non-stress conditions or vise versa. The pod length has a high and positive correlation with the number of seed per pod, the number of seed per plant, the seed yield and the seed thickness. It indicates that selecting the pod length and the number of seed per pod can, indirectly, by increasing the number of seed per plant, increase the yield. Reference [25] shows in their research reported that the pod length and number of pod has a high correlation with the seed yield. In stress conditions (TABLE III), the seed yield had a positive and significant correlation with the harvest index (0.816), the number of seed per plant (0.740), the number of pod (0.729), the number of seed per pod (0.540), the pod weight (0.500), the biological yield (0.496) and the pod width (0.333), respectively. Also Reference [17] shows in their investigation on the Red bean, obtained the most correlation of the seed yield, in the non-stress conditions, with the biological yield (0.911) and in stress conditions with the harvest index (0.714). In the stress conditions, 100-seeds weight shown a very high and significant correlation with the seed length, but its correlation with the seed thickness was negative. This fact is in agreement with the result of changes percentage in the stress conditions, because among the seed length, width and thickness characters, the seed length had the least effect and the seed thickness had the most effect due to stress. Therefore, in the stress conditions, the seed weight has a very high correlation with the seed length and a positive correlation with the seed width, therefore in stress conditions seed weight can be a criterion instead of the seed length and width.

Generally, it shows that appearing of correlation between various characters in two stress and non-stress conditions has differences due to the effective condition influences on the characters. While in stress conditions, the harvest index had a negative significant correlation with height but in the non-stress conditions; it shows a positive correlation with the height. It can be resulted that in stress conditions, selecting the more dwarf lines with more harvest index may cause in the increase of the yield. Confirming this fact, it was observed that in the non-stress conditions, height had a positive and very significant correlation with the yield and its components, while this character in stress conditions shown a negative significant correlation with the number of seeds in the pod. It also had a negative correlation with the yield.

TABLE II
SIMPLE CORRELATION OF WHITE BEANS IN THE NON-STRESS CONDITIONS

	Biological yield	Seed yield	100-seed weight	Seed thickness	Seed width	Seed length	Number of seed per plant	Number of seed per pod	Pod width	Pod length	Pod weight	number of pod	High
Number of pod	0/322*												
Pod weight	0/340*	0/160											
Pod length	0/135	-0/216	0/263										
Pod width	0/505**	-0/137	-0/194	0/021									
Number of Seed per pod	0/598**	-0/077	0/243	0/609**	0/42**								
Number of Seed per plant	0/676**	0/47**	0/269	0/36**	0/266	0/76**							
Seed length	0/197	-0/154	0/129	-0/228	0/330*	0/136	-0/122						
Seed width	-0/188	-0/217	-0/188	-0/209	-0/30*	-0/32*	-0/53**	0/292					
Seed thickness	-0/064	-0/49**	-0/259	0/38**	0/45**	0/38**	-0/104	0/311	0/199				
100-seed weight	-0/58**	-0/47**	-0/159	0/215	-0/253	-0/014	-0/32*	-0/199	0/39**	0/406**			
Seed yield	0/360**	0/435**	0/136	0/320*	0/015	0/59**	0/786**	-0/029	-0/122	0/084	0/086		
Biological yield	0/263	0/346*	0/34*	0/450**	-0/107	0/47**	0/72**	-0/240	-0/142	-0/054	0/160	0/841**	
Harvest index	0/158	0/417**	0/103	-0/040	-0/017	0/40**	0/51**	0/156	-0/083	0/191	0/038	0/793**	0/38**

TABLE III
SIMPLE CORRELATION OF WHITE BEANS IN THE STRESS CONDITIONS

	Biological yield	Seed yield	100-seed weight	Seed thickness	Seed width	Seed length	Number of seed per plant	Number of seed per pod	Pod width	Pod length	Pod weight	number of pod	High
Number of pod	0/269												
Pod weight	0/214	0/455**											
Pod length	-0/371*	-0/346*	-0/36*										
Pod width	0/321*	-0/45**	0/40*	-0/337*									
Number of seed per pod	-0/331*	-0/043	-0/25	0/428**	-0/030								
Number of seed per plant	0/127	0/799**	0/31*	-0/186	-0/47**	0/309*							
Seed length	-0/51**	-0/160	-0/15	0/440**	-0/375**	0/152	-0/038						
Seed width	0/050	-0/222	-0/012	0/058	0/375**	-0/179	-0/021	0/425**					
Seed thickness	0/114	-0/210	-0/035	0/128	0/069	0/266	-0/157	-0/41**	-0/290				
100-seed weight	-039**	-0/301*	0/263	0/221	-0/224	0/187	-0/147	0/653**	0/214	-0/003			
Seed yield	-0/11**	0/729**	0/51**	-0/042	0/333*	0/54**	0/74**	0/207	-0/068	-0/043	0/216		
Biological yield	0/191	0/490*	0/69**	0/019	0/303*	0/34*	0/242	-0/155	-0/080	-0/016	0/036	0/496**	
Harvest index	-0/34*	0/427**	0/198	-0/113	0/120	0/61**	0/62**	0/384**	-0/002	0/078	0/352*	0/816**	-0/04

D. Stepwise Regression and Path Analysis:

The results of stepwise regression analysis in White bean under stress and non-stress conditions was calculated by considering the seed yield as the dependent variable and other characters as the independent variables. In the non-stress conditions, three characters; the biological yield, the harvest index and the number of seed per pod were in turn, entered to the regression model (TABLE IV) which accounted for 98.41% of the seeds yield changes. These results are in agreement with those of correlation so that, the biological yield character which was first entered into the regression model, had the most correlation with the yield and the harvest index and the number of seed per pod had a very high correlation with the yield.

TABLE IV
THE RESULTS OF STEPWISE REGRESSION ANALYSIS UNDER NON-STRESS CONDITIONS

Character entered to the model	R	R^2	R adj^2	Standard error
Biological yield	0/837	0/707	0/743	2/611
Harvest index	0/977	0/971	0/943	1/196
number of seed pod	0/977	0/984	0/943	1/196

Considering that by entering of these three characters into the regression model, a high percentage of yield changes were justified, to determine the direct and indirect effects of these characters, the path analysis (TABLE V) was performed. In the study of the seed yield by the biological yield, it was observed that this character had the highest direct, positive effect (0.580) on the seed yield and its indirect effects by the harvest index was relatively high and positive, but by the number of seed per pod, it was positive but not remarkable. Generally, the direct and indirect effects of the biological yield by the harvest index may be considered in increasing the yield. Reference [17] shows that in the non-stress conditions, the biological yield has the highest direct, positive relationship with the bean yield and obtained its amount as 0.74. The seed yield by the harvest index, this character had a very high direct, positive effect on the grain yield (0.524) and a positive, indirect, relatively high effect by the biological yield. Thus, in this character, like the biological yield, the direct and indirect effects by the harvest index can be considered in increasing the yield. The seed yield by the number of grains in the pod, this character has a positive, direct and relatively high effect (0.133), and by the biological yield and the harvest index, has indirect, very high effects. The direct and indirect effects of this character can be considered in increasing the yield.

TABLE V
DIRECT & INDIRECT EFFECTS CHARACTERS UNDER NON-STRESS CONDITIONS

yield	Biological yield	R^2 Harvest index	number of seed pod
Biological yield	<u>0/580</u>	0/198	0/062
Harvest index	0/219	<u>0/524</u>	0/049
number of seed pod	0/272	0/193	<u>0/133</u>

In the stress conditions, three the harvest index, the biological yield, and the number pods characters were entered into the regression model, in turn and accounted for 96.3% of the changes in the seed yield. These results are in agreement with the correlation result, in which the characters of the harvest index, the biological yield, and the number pods had a very high correlation with the yield.

TABLE VI
STEPWISE REGRESSION ANALYSIS UNDER STRESS CONDITIONS

Character entered to the model	R	R^2	R adj^2	Standard error
Harvest index	0/916	0/665	0/639	3/095
Biological yield	0/974	0/950	0/941	40568
Number of pod	0/985	0/971	0/963	0/99

The path analysis was performed to determine the direct and indirect effects of these characters on the yield (TABLE VII). In the study of the seed yield by the harvest index, this character had the highest direct, positive effect (0.752) on the grain yield. Also Reference [17] stated that in the stress conditions, the harvest index had the highest direct, positive relationship (0.785) with the bean yield. The seed yield by the biological yield, this character has a very high, direct, positive effect on the seed yield, but its indirect effects are not high, therefore, this character, itself can be directly used to increase the yield. The seed yield by the number of pods, this character has a relatively high, positive, direct effect (0.194) and has a very high indirect effect by the harvest index and the biological yield. In the study of the correlation of the number of seed per pod in the non-stress conditions and the number of pods in the stress conditions, a high correlation with the yield was observed due to the total direct and indirect effects of these characters by the harvest index and the biological yield.

TABLE VII
DIRECT AND INDIRECT EFFECTS CHARACTERS UNDER STRESS CONDITIONS

yield	Harvest index	Biological yield	Number of pod
Harvest index	0/752	-0/02	0/083
Biological yield	-0/034	0/434	0/095
Number of pod	0/321	0/212	0/194

Generally, it can be concluded that in the non-stress conditions, considering the characters of the biological yield, the harvest index, and the number of seed per pod and in the stress conditions, proper selection of genotypes, considering the characters of biological yield and the number of pods can cause in the increase and constancy of the yield. As we know, breeders are interested in identifying the other characters than yield to use them as a criterion in selecting parents. Path analysis provides this possibility to identify the effective characters better, and apply them to increase the yield.

E. Factor Analysis:

The results of factor analysis are represented in TABLE VIII. It should be mentioned that the variance of each factor shows its importance, on the other hand, the sign of factors' coefficients in each factor represents the relationship between these characters. The first factor, with the most explanation for the changes, had variance of 24.9%, in which the characters of the biological yield, the harvest index, the number of seed per pod, the number of seed per plant and the seed yield existed. Here, the sign of all of the characters is positive. Considering the characters importance in this factor, the first factor may be called the yield and first-class components of the yield's factor. In a survey on the bean by in the results of factors analysis in the non-stress conditions, the first factors accounted for 24.5% of the yield changes [17]. It was consisted of the characters of the biological yield, the harvest index, the number of seed per pod, the number of seed per plant and the seed yield, indicating the importance of these characters in breeding the yield in the bean. It's shown in this factor that by increasing the number of seed per pod, the number of seed per plant increases and may increase the seed yield which is in agreement with the results of stepwise regression results. The second factor, consisting of the seed width, the pod weight and the height, included 19.5% of the total changes. According the characters of this factor, it can be called the growth factor. The third factor, consisting of 100-seed weight, the seed thickness, the pod length and the number of pod, accounted for 16.9% of the yield total changes. This factor may be called the second-class components of the yield. The fourth factor, accounting for 16.2% of the total changes, consisted of the pod width and the seed length, which can be called the pod width factor. Altogether, the factors analysis model explained 77.5% of the total in the data for all characters. In addition to grouping the characters, the multi-factor analysis also shows the characters' importance and their relationship with each other. For breeding of yield, those characters with higher level of importance should be used.

TABLE VIII
- THE RESULTS OF FACTORS ANALYSIS UNDER NON-STRESS CONDITIONS

characters	Yield factor and first-class yield components	Reproductive factor	second-class components of the yield	pod width factor
number of seed per plant	0/718	-0/489	0/461	0/417
Seed yield	0/980	-0/138	0/070	-0/002
Harvest index	0/869	0/241	-0/117	0/159
number of seed per pod	0/521	-0/489	0/461	0/417
Biological yield	0/758	-0/371	0/184	-0/288
Pod weights	0/063	-0/573	-0/040	-0/135
Seed width	-0/045	0/694	0/107	-0/075
height	0/303	-0/565	0/202	0/473
Seed thickness	0/104	0/318	0/729	0/458
number of pods	0499	-0/194	-0/723	-0/122
100-seeds weight	0/105	0/457	0/674	-0/423
Pod length	0/215	-0/481	0/711	-0/133
Pod width	-0/039	-0/197	0/164	0/838
Seed length	0/005	0/307	-0/048	0/690
variance	24/9	19/5	16/9	16/2
Cumulative variance	24/9	44/4	61/3	77/5

The results of factor analysis in the stress conditions are provided in TABLE IX. Generally, 4 factors explained totally 76% of the data. The first factor, accounted for 24.1% of the data changes, consisted of these characters: the seed yield, the number of seed per pod, the harvest index, the number of seed per pod and the number of pods. This factor is called the yield and the first-class components of the yield's factor. Because this factor is related to the number characters, it also may be called the number factor. This result is in accordance with the results of the characters simple correlation, step wise regression and path analysis in which, all characters in the first factor had a positive, very significant correlation with the yield. It the path analysis, it was shown that the harvest index and the number of pods have a high, direct, positive effect on the seed yield. Therefore, these characters are important in breeding the bean yield in the non-stress conditions so that the direct and indirect increasing of these characters may cause in the increase of the yield. The second factor, consisting of the pod length, the pod width and height, explained 22.14% of the total changes of the data. This factor can be called the size or growth factor. Reference [11] shows the factor analysis; to study the morphologic characters and the yield components in the bean genotypes, represented three factors. The first factors included the characters of the seed weight, the pod weight, the pod thickness, the pod length and the lower knots length; they named this factor as the size factor. These researchers declared that the negative effect for some characters is in accordance with the compensative role, which happens generally among the yield components. The third factors, accounted for 15.7% of the data changes, including the pod weight, the biological yield and 100-seed weight. The biological yield has a higher factor coefficient. Referring to the correlation matrix, it's clear that it has a very high correlation with the yield also the path analysis showed that the biological yield had a direct, positive and high correlation with the yield. Thus, this factor can be called the biological yield factor or the second-class yield factor. The fourth factor includes 100-seed weight, the seed length and the seed width and accounts for 14.8% of the data changes. This factor is called the seed characteristic or the 100-seed weight factor. As it is clear, these results are in agreement with those of the correlation of the characters i.e. the seed length and the seed width, both like the 100-seed weight entered into a factor and are co-sign and positive. So the seed weight can be used instead of these two characters, and to increase the 100-seed weight, the seed with more length and width can be selected. Reference [3] shows totally four factors in multi-factor analysis which accounted for 79% of the data total changes. The first factor (the growth factor) 29%, the second factor (the yield first-class components) 21%, the third factor (second-class components of yield) 18%, the fourth factor (the number of sub stems) 9.8% of the variety, which the 1st and 4th factors are known as the growth factors and the 2nd and 3rd are related to the yield.

Generally, the factor analysis is applied to reduce the data, identify the main yield components, grouping of the characters based on the inter-relations among them and study the genetic diversity, thus the factor analysis can be the complementary of the step wise analysis and also the path analysis and provides additional information [3]-[9]-[33]. Totally, it can be concluded that we can use the factor analysis method as an application device to identify the importance and management of the relationship between the characters with the seed yield. Considering the relationship between the seed yield and the mentioned results, this method may be applied as a proper criterion in selecting the desirable yield lines which are the important breeding bases. Of course, for more comprehensive studies, it is necessary to test with more characters and repeat the test in different environmental conditions to have more accurate results.

TABLE IX
THE RESULTS OF FACTORS ANALYSIS UNDER STRESS CONDITIONS

characters	Yield factor and first-class yield components	Reproductive factor	second-class components of the yield	pod width factor
number of seed per plant	0/898	-0/166	-0/028	-0/185
Seed yield	0/893	-0/085	-0/381	0/116
Harvest index	0/898	0/118	0/036	0/264
number of seed per pod	0/642	0/442	0/371	-0/039
Biological yield	0/604	-0/482	-0/321	-0/200
Pod weights	-0/005	0/634	0/050	0/163
Seed width	0/234	-0/801	-0/133	0/118
height	-0/174	-0/827	0/059	-0/223
Seed thickness	-0/035	0/237	-0/710	0/009
number of pods	0/142	-0/489	-0/706	0/181
100-seeds weight	0/134	-0/217	-0/850	-0/083
Pod length	0/151	0/433	0/029	0/785
Pod width	-0/167	-0/302	0/124	0/811
Seed length	0/100	0/360	-0/220	0/705
variance	24/1	21/4	15/7	14/8
Cumulative variance	24/1	45/5	61/2	76

F. Drought Indices:

In this research, different resistance to drought indices were calculated by the genotypes yield in the stress (ys) and non-stress (yp) conditions. Reference [13] shows the most suitable selection criterion in the stress conditions must be able to separate the genotypes with desired and similar display in both conditions. Considering that the best indices are those with high correlation with the yield in both stress and non-stress conditions, to be able to distinguish the genotypes with desired and similar display in both conditions from other genotypes, the correlation between the yield and different indices was calculated (TABLE X). It is observed from the correlation matrix that the STI, GMP and MP indices have this characteristic. Because these indices have a positive, very significant correlation with the genotypes yield in both stress and non-stress conditions, thus the genotypes with high amount of these induces may be identified as the most resistant genotypes.

The correlation between Yp and Ys was positive and significant, equal to 0.45. Szilagy., 2003 on his research on the White bean, found a positive relationship between the seed yield in the stress and non-stress conditions [33]. Reference [28] shows that the correlation between Ys and Yp is between 0 and 0.5, and the breeder's desired condition is the situation in which the correlation between yields in two conditions is strongly positive. Under these conditions, MP and TOL will have a positive correlation; therefore the selection of genotypes based on the yield in the non-stress conditions will cause in an increase in the yield mean in the stress conditions.

The SSI index had a positive, very significant correlation with the yield in the non-stress conditions, but in the stress conditions, its correlation with the yield was negative. Therefore, the genotypes with lower amounts of this index will be identified as the sufferer genotypes. Selecting based on the SSI index may cause in the selection of genotypes suffering stress with low yield potential [15]-[28]. Thus, it's not advisable to select based on this index. Also, selecting based on the TOL index may cause in the selection of genotypes with low Yp and MP [15]-[26]. For example, genotypes number 10, 14, 5, 4 and 8 don't have sound ranks with the Yp and MP indices, and may not be placed in the preferable genotypes group by these two indices. The genotypes, just because produced similar yields in the water stress and non-stress conditions; will be selected by the TOL index. On the other hand, Reference [26] shows stated that if the yield in the stress and non-stress conditions is negative and the purpose is to increase the yield in the stress conditions, selecting based on TOL will be useful. It should be considered, however, that this selection will decrease the yield and the productivity mean in the non-stress conditions. In these conditions, selecting based on MP will reduce the yield in the stress conditions. So, the TOL index cannot be useful in this research, but MP is useful because as stated by [26] shows if the correlation of Ys and Yp is positive and significant, like this research, selecting based on MP will cause in the selection of genotype with high yield in both conditions.

TABLE X
DIFFERENT CORRELATION INDICES RESISTANT TO STRESS AND THE YIELDS

	Yp	Ys	TOL	SSI	MP	STI
Ys	0/456*					
TOL	0/853**	-0/014				
SSI	0/338	-0/657**	0/771**			
MP	0/930**	0/734**	0/607**	-0/010		
STI	0/739**	0/923**	0/287	-0/344	0/926**	
GMP	0/746**	0/933**	0/289	-0/364	0/934**	0/993*

The results of studying the level of genotypes resistance to the drought stress are provided in (Table XI). In this table, for 15 lines of the White bean, the values of Yp, Ys, TOL, SSI, MP, STI and GMP and also the results of genotypes ranking based on this index is available. First, 5 preferable genotypes were selected based on the Yp, Ys, TOL, SSI, MP, STI and GMP indices, separately (TABLE XII), then, by the results of these selections, some of the best genotypes were selected. According to the table, the genotypes selected by GMP, STI and MP include the genotypes with desired yield in both conditions. Finally, the genotypes selection was performed based on high values of GMP, STI and MP, and then to assure the stability of the yield in the stress conditions, the genotypes, from the selected genotypes, with the highest values of Ys were selected. Based upon this, the lines 9.KH-41234, 12.KH-41128, 6.KH-41232 and 11.KH-41124 were selected as the resistant genotypes. This research showed that, the indices GMP and STI are suitable indices in the bean which can be applied for yield stability and reaching the cultivars with high yield in both conditions. It also indicated that if there is a positive, significant correlation between yields in the stress and non-stress conditions, the MP index will function like two STI and GMP indices. Generally, the genotypes were divided into 4 general groups; the genotypes with proper yield in both conditions (6, 12, 9, 11), the genotypes with proper yield just in the non-stress conditions (3, 7, 1), the genotypes with proper yield just in the stress conditions (13, 14, 5) and the genotypes with low yield in both conditions (2, 4, 8, 15, 10).

TABLE XI
THE GENOTYPES SELECTED BASED ON DIFFERENT INDICES

	Yp		Ys		TOL		SSI		MP		STI		GMP	
Line		rank		rank		rank		rank		rank		rank		rank
1	38/08	7	8/34	13	29/73	11	1/24	13	23/20	10	0/23	12	17/82	12
2	34/17	9	12/93	10	21/24	9	0/99	10	23/55	7	0/32	8	21/02	8
3	48/10	3	7/66	14	40/44	15	1/32	15	27/88	4	0/27	11	19/19	11
4	25/53	14	10/60	11	14/93	4	0/93	9	18/06	14	0/20	13	16/45	13
5	28/53	13	13/76	8	14/76	3	0/82	3	21/14	13	0/29	10	19/8	10
6	42/27	4	21/53	2	20/74	8	0/78	2	31/9	3	0/67	2	30/17	2
7	38/97	6	6/70	15	32/27	13	1/32	14	22/83	11	0/19	14	16/16	14
8	31/20	11	13/50	9	17/7	5	0/90	6	22/35	12	0/31	9	20/52	9
9	54/70	1	25/66	1	29/04	12	0/845	4	40/18	1	1/03	1	37/46	1
10	20/93	15	8/64	12	12/28	1	0/93	8	14/78	15	0/13	15	13/45	15
11	39/10	5	16/23	5	38/06	14	1/11	11	35/26	2	0/42	4	29/68	3
12	54/30	2	14/56	4	20/33	7	0/93	12	24/73	6	0/65	3	22/54	5
13	34/90	7	16/63	6	13/66	2	0/71	7	23/46	8	0/37	5	22/44	6
14	30/30	12	14/20	3	18/1	6	0/91	1	23/25	9	0/37	6	21/41	7
15	32/30	10	14/56	7	20/33	7	0/93	5	24/73	6	0/34	7	22/54	5

TABLE XII
THE GENOTYPES SELECTED BASED ON DIFFERENT INDICES

Genotypes Selected	indices
9, 12, 3, 6, 11	Yp
9, 6, 14, 12, 11	Ys
10, 14, 5, 4, 8	TOL
15, 9, 5, 6, 14	SSI
9, 12, 6, 3, 11	MP
6, 12, 9, 11, 13	STI
6, 12, 9, 11, 13	GMP

G. Cluster Analysis:

In order to determine the variation among different genotypes and determination of the genotypes far or nearness, the Cluster Analysis by the UPGMA method was applied to place the similar cultivars in one group. The purpose is to specify the samples with the most distance from each other to be used in hybridization programs and provide required variation for breeding programs. Also, by grouping the individuals in similar groups, the amount of breeding works and the costs of researches will reduce. In the Cluster Analysis, the lines were divided based on the similarity percentage of 75% in stress and non-stress conditions into 5 groups (Figure 1 & 2). In the non-stress conditions, the genotypes 1, 7 and 2 were placed in the first group. These genotypes had an intermediate rank in the non-stress conditions. The genotype 9 was placed in the second group, the genotype 6 in the third group, the genotypes 3, 11 and 12 were placed in the fourth group. As it is observed, 5 preferable genotypes with due regard to the yield, were placed beside each other but in three separate groups. It shows that confluence of these genotypes may be useful in increasing the variation since they are in three separate groups. Also they can be used to transfer the high yield to each other because they are beside each other and are genetically similar which is useful for breeding programs. In the fifth group, the genotypes 4, 10, 5, 8, 13, 15, and 14 were placed which had low yield in the non-stress conditions. In the stress conditions, also, the lines were divided into 5 groups. In the first group, genotypes 5, 6 and 9, in the second group, genotypes 1, 10, 4 and 7, in the third group, genotypes 8 and 15, in the fourth group, genotypes 11 and 13 and in the fifth group, genotypes 3, 2, 12 and 14 were placed.

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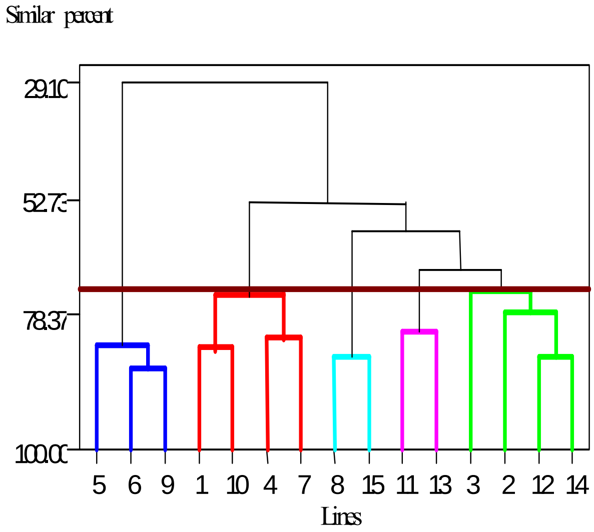

Fig.1 The Cluster Analysis of White Bean 15 Lines in the Non-Stress Conditions

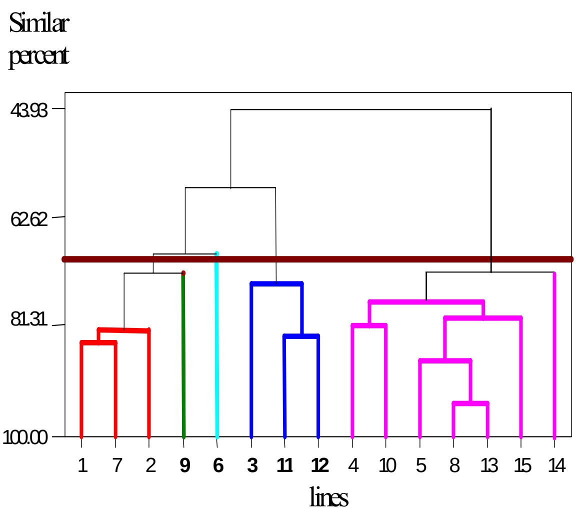

Fig.2. Cluster Analysis of 15 White Bean Lines in the Stress Conditions

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