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Study of Qualitative and Quantitative Traits in Red Bean in Non-Stress and Drought Conditions

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Abstract: This study was conducted in order to evaluate the effect of water stress (limited irrigation) on different traits of bean. Fifteen bean genotypes were planted in a randomized complete block design with three replications under non-stress and drought stress conditions (24 traits were recorded). The results showed, the most decrease in the bean has been the plant yield. The results of step wise regression showed that the length of the longest pod and the number of pod per plant under non-stress condition and 100-seed weight, number of seed per plant and days of cotyledon leaves appearance under stress condition had the most effect on the yield. Since all of these traits showed us a considerable changes in yield, to study of direct and indirect effects these traits were used. Results analysis indicated a high direct affects of traits in non-stress conditions and there were no conspicuous indirect affects in these traits. Direct affects of 100-seed weight, seed number per bush in stress condition was very high, but indirect affects showed a weak consequence. As a result a direct selection is suggested for these traits. Direct affects of day's number till the leaves appearance was less considerable in compare with two previous traits and also indirect affects were unwanted. In resistance amount studying, indirect affects of tolerance's susceptibility and also traits changes percentage in stress conditions were measured. Geometric Mean Productivity (GMP), Stress Tolerance Index (STI) and Mean Productivity (MP) were the most suitable indicators for selecting drought resistant genotypes. Based on these indicators KS-31146 and KS-31150 in red beans, were found as resistant genotypes.

Key words: Bean, drought resistance index, limited irrigation, non-stress irrigation, simple regression

INTRODUCTION

In an increasingly vulnerable world, nations, communities and individuals are confronted daily with suffering and loss of lives and livelihoods resulting from disasters triggered by natural and human-induced hazards. The population growth rate in under-development countries has shown unexpected results. Drought is a slow-onset hazard, which provides time to consider and address its complex root causes, such as understanding people's vulnerabilities and identifying unsafe conditions related to poverty, fragile local economy, livelihoods at risk, lack of strategies and plans, limited institutional capacities and resources. Understanding these issues allows government authorities and the public to undertake effective drought mitigation and preparedness measures. Food availability limitation and malnourishment are the most important problems in today's society (Timothy *et al*., 2000). Different studies show that using herbaceous proteins will decrease the harmful effects of protein shortage. Grain and especially bean, consist considerable amount of protein (various beans subfamily include 20-50% protein).

The effect of soil moisture stress on dry bean has been well documented (Boutraa and Sanders, 2002). Many methods have been employed to identify crop lines that are productive in dry environments (Begg and Turner, 1976; Yadav and Bhatnagar, 2001; Reynolds *et al*., 2007). Some use mathematical models to compare the change in seed yield between stressed and non-stressed environments (Mederski and Jeffers, 1973; Keim and Kronstand, 1979; Rosielle and Hamblin, 1981). Singh (1999) compared four yield based selection indices for identifying high-yielding dry bean lines under soil moisture deficit. The indices included the arithmetic (AM) and geometric means (GM) of seed yield in stress and nonstress environments, response of seed yield to drought across stress and nonstress environments (RD) and percent reduction in seed yield across stress and nonstress environments (PR) and reported that AM and GM were both useful in identifying high-yielding lines, but ranked the lines in different orders, whereas PR and

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RD were not useful for identifying drought-tolerant lines. Samper and Adams (1985) also suggested that GM was useful for identifying high-yielding dry bean lines in water stress environments.

Singh (2007) has conducted an experiment to study the affect of drought on bean. The research result has reported that the average yield reduction in drought condition (stress) was 60% and seed weight reduction was 14%. Yield seed weight and maturity had positive correlation in both stress and non-stress conditions. German *et al.* (2006) have shown the drought resistant genotypes should be used for determining irrigation frequency, amount of water to be applied and mechanisms of resistance and for identifying, mapping and pyramiding favorable genes for dryland and irrigation-assisted sustainable production systems and also reported that seed yield in both non-stress and stress conditions, had positive correlation. In other experiment Hayes and Singh (2007) reported that drought has made reduction in yield average (68%) and seed weight (11%), respectively. Santalla (2001) had done a study on 13 morphological traits and expressed that the seed yield has correlation significant with the pod number. Rosales-Serna (2004) has reported that day's number till flowering has a negative correlation with the yield. Acosta-Diaz *et al.* (2004) expressed that except physiological adaptation and high harvest indicator under drought condition, a high yield potential is an important factor for yield permanence. Due to the Souza's (2003) report permanence is a suitable indicator for genotype behavior and could be used in breeding. Abebe *et al.* (1998) calculated six selected indices, including arithmetic mean (AM), geometric mean (GM), drought response index (DRI), susceptibility index (S), response to drought (RD) and percent reduction (PR), to determine correlations between indices and yields in stress (Y_s) and non-stress (Y_{ns}) environments. AM and GM were the only indices positively correlated with both Y_s and Y_{ns}.

In the present research we attempt to study the qualitative and quantitative traits in red bean in two different conditions including non-stress and drought as well as compare those conditions.

MATERIALS AND METHODS

The study was conducted in national research station of bean in Khomein city, Iran on 25th July 2006 to 25th July 2007. In this experiment 15 genotypes of white bean were studied in randomized complete block in two conditions, non-stress (4 days irrigation) and stress (10 days irrigation) with three replications (Table 1). Each experimental unit was included 3 lines with 2.5 m length. Distance between lines was 50 cm and distance between bushes on each line was 10 cm. In first three leaflet level, stress was done in three replications (water stress) and has progressed till the end of growth.

Total 7 bushes were selected by chance after omitting rows, margins, first and last points of lines. All the studies were done on the 7 selected bushes. Twenty four traits include vegetative, generative level and yields were studied. Then in order to study the variety in traits between the study genotypes, we did a simple variance analysis on each trait in both stress and non-stress (non-stress) conditions. Furthermore we have compared the result of traits average, regression, path, factors, cluster analysis and traits correlation in both conditions.

To find the drought resistance, we used the indicators explained in following formula:

- $$\text{Percent of changes in traits} = \frac{\text{Amount of traits in non-stress condition} - \text{Amount of traits in stress}}{\text{Amount of traits in non-stress condition}}$$
- Indicator of sensitiveness to stress (Fisher and Maurer, 1998) $SSI = \frac{1-(Y_S/Y_P)}{1-(\bar{Y}_S/\bar{Y}_P)}$
- Indicator of tolerance to stress (Rosielle and Hamblin, 1981) $TOL = Y_P - Y_S$
- Average production $MP = \frac{(Y P) + Y_S}{2}$
- Indicator of tolerance to stress (Fernandez, 1992) $STI = \frac{(Y_P)(Y_S)}{(\bar{Y}_P)^2}$
- Average of production (Fernandez, 1992) $GMP = \sqrt{(Y_S)(Y_P)}$

As has shown, different indicators are defined due to these parameters:

Y_P = A specific genotype yield in non-stress condition
Y_{ns} = A specific genotype yield in non-stress condition
Y_S = A specific genotype yield in stress condition
$\bar{Y}_P$ = All genotypes average yield in non-stress condition or non-stress condition
$\bar{Y}_S$ = All genotypes average yield in stress condition

Statistical analysis: In each environment to find the yield details, step by step regression analysis was applied. Path analysis was done to find the direct and indirect effects of high correlation traits, which leads to find out the most affective traits on yield. Cluster analysis was applied to

Table 1: The 15 interested genotype of bean

No. of genotype	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Genotypesof bean	KS-31142	KS-31138	KS-31113	KS-31124	KS-31121	KS-31127	KS-31125	KS-31139	KS-31137	KS-31155	KS-31146	KS-31119	KS-31150	KS-31166	KS-31151

find the genetic variety and traits in each environment. Statistic calculations were done by use of SPSS 12.5, SAS 6.5 and Minitab 13. 31. The p-value <0.05 consider as a significant and p<0.001 consider as a highly significant.

RESULTS

The red bean variance analysis in non-stress condition showed that variety in R_5 (When 50% of population have their primary bud); R_6 (When 50% of population in each line have showed their first flower); R_7 (When 50% of population in each line have showed their fullness of podding); R_8 (When the first pod appearances in 50% of population); R_9 (When the pods holes are completed and seeds have their maximum weight), bush type, seed number in pod, seed number in bush, 100 seed weight, height, steam diameter, number of nodes, highest pod length and shoot dry weight, there were high significant differences. In case of the other traits there were no significant differences. In stress condition there were high significant difference for R_7, R_5, bush type, seed number in pod, 100 seed weight, bush height, height of internodes, steam diameter, number of nodes, highest pod length and leaf number in bush. Also for R_6, R_8, R_9, branches number, leaf dry weight in bush there were significant difference and it shows the high rate of variety between traits. According to the results the most damage of drought condition that we have observed, was single bush yield (44.33%). This damage is a result of high reduction in seed number in bush (40.92%), pod number in bush (25.43%), seed number in pod (20.27%) (Table 2). In confirming of our findings, German *et al.* (2006) have shown that, main factors affecting by drought condition are the biomass reduction, seed yield, harvest indicator and seed weight.

Due to the significant difference between genotypes, in order to arrange the genotype an average comparison was done by Duncan's test. The test showed that in non-stress and stress conditions the most yields were observed for genotype 13 (24.01 and 15.07 g, respectively). German *et al.* (2006) reported a positive correlation for seed yield in stress and non-stress conditions. We find out that the seed yield is a dependent variant based on the red been step wise regression results in both non-stress and stress conditions. Also we found that the rest of the traits are independent variants. In non-stress condition, the highest pod length and pod number were two traits for ultimate model (these two traits caused 69% of changes). The results was very close to correlation results, that the highest pod length had the strong positive correlation with yield (r = 0.689), but the pod number had less positive correlation with yield (r = 0.419) in compare with the highest pod length (Table 3). In confirming this finding the information of the research has done by Santalla *et al.* (2001), which mentioned traits explained the most part of yield changes,

Table 2: Mean of traits and percentage of variance in 15 genotype of red bean under the normal and stress condition

Traits	Mean of traits in non stress conditions	Mean of traits in stress conditions	Percent of changes
The number of days to appearance of bud	8.26	8.91	-7.86
The number of days to appearance of first leaves	10.15	10.37	-2.16
The number of days to appearance of first three leaflet	16.26	16.22	0.24
The number of days to appearance of tired three leaflet	21.88	22.13	-1.14
The number of days to stage of budding	41.35	41.08	0.65
The number of days to flowering	47.48	47.53	-0.10
The number of days to podding	51.11	51.26	-0.29
The number of days to fullness of podding	81.35	83.66	-2.83
The number of days to appearance of maturation	88.48	90.42	-2.19
Type of bush	1.44	1.57	-9.02
Number of pod per plant	15.41	11.49	25.43
Number of seed per pod	3.70	2.95	20.27
Number of seed per plant	56.74	33.52	40.92
100-seed weight	33.07	29.67	10.28
Yield of a plant	18.27	10.17	44.33
Height of plant	47.37	46.83	1.13
Height of internodes	4.70	4.81	-2.34
Diameter of steam	5.81	5.64	2.92
Number of subphylum	4.89	4.16	14.92
Number of nodes	10.36	10.02	3.28
Length of tallest pod	11.02	9.58	13.06
Number of leaves per plant	70.63	72.66	-2.87
Dry weight of leaves per plant	5.95	5.04	15.29
Dry weight of shoots	30.03	20.73	30.96

Table 3: The results of path analysis in 15 genotype of the red bean under the non-stress condition

	Length of the tallest pod	No. of the pod per plant	Total correlation
Length of the tallest pod	0.654	0.035	0.689
Number of the pod per plant	0.065	0.354	0.419

to find the direct and indirect affects these two traits were used. The results showed that the highest pod length direct effect on yield was 0.654 and the indirect effect was not noticeable. So this trait is suggested for breeding. The pod number direct affect on yield is (0.354) that in compare with the highest pod length is less important (Table 3). Also there is no noticeable indirect affect in it.

The final model regression in stress condition was studied for 100 seed weight, seed number in bush and V_2 that three traits caused more than (69%) of changes. Then we apply the correlation coefficients in path analysis to find the direct and indirect effects. The 100 seed weight direct effect is (72%) that is very high and positive, but it's indirect effect by seed number in bush (-0.14) and V_2 (-0.05) was not noticeable (Table 4). So a direct selection of this trait is suggested to improve the bean yield. The seed number direct effect is high and positive (0.75) but it's in direct effect is not noticeable, so its direct affect is suggested for breeding (Table 5). The V_2 (Days till primary leaves appearance) is less important than the two previous traits to breed. The path analysis result were close to the other researcher results, such as Santalla which reported seed yield correlation with pod number is positive and very significant (Santalla *et al*., 2001). Factors analysis showed in non-stress condition for each of the amounts more than 1, 6 factors (that explained 89/5% of changes) were found. Also in stress condition 6 factors were studied that explained 90/63% of all changes.

In case of indicators MP, STI and GMP were showed the significant correlation with yield. We do our selections with these mentioned indicators. To study of yield permanent in stress condition, between all genotype, the genotypes with a high rate (YS) are selected. (For example genotypes number 11 and 13) according to the Fernandez (1992) views, suitable genotypes are those which are useful and positive in both conditions. The cluster analyses were applied to study of variety between different genotype and find the genotype relation. In non-stress condition, after cluster cutting, genotypes divided into there clusters. The first clusters included genotypes: 6, 15, 11, 13 (Table 6). The second cluster included genotypes: 8, 10, 1, 2 and the third cluster. As it has shown resistance genotypes are in first cluster. So, we can name the first cluster as resistance genotypes cluster (Fig. 1, 2). In breeding, cluster analysis is too much valuable as Romesburg (2004) and McClean *et al*. (1993). Due to this fact that the most damage in drought

Table 4: The result of path analysis in 15 genotype of the red bean under the stress condition

	100-seed weight	No. of the seed per plant	V_2	Total correlation
100-seed weight	0.72	-0.14	-0.05	0.52
No. of the seed per plant	-0.13	0.75	0.05	0.21
V_2	-0.18	0.18	0.22	0.21

Table 5: Correlation coefficient of yields and drought resistance indexes in the non-stress and drought condition in 15 genotypes of red bean

	Y_P	Y_S	TOL	SSI	MP	STI	GMP
Y_P	1.00	0.706**	0.559*	-0.023	0.936**	0.872**	0.888**
Y_S		1.00	-0.192	-0.718**	0.910**	0.951**	0.952**
TOL			1.00	0.809**	0.232	0.096	0.16
SSI				1.00	-0.37	-0.481	-0.485
MP					1.00	0.982**	0.993**
STI						1.00	0.993**
GMP							1.00

*Significant differences ($p<0.05$), **Highly significant differences ($p<0.001$)

Table 6: Evaluated genotypes based on different indexes

	Y_P*		Y_S*		TOL*		SSI*		MP*		STI*		GMP*	
Genotype	Mount	Level	Mount	Level	Mount	Level	Mount	Level	Mount	Level	Mount	Level	Mount	Level
1	16.62	11	10.36	9	6.26	12	0.85	11	13.49	10	0.51	10	13.12	10
2	21.29	3	9.64	10	0.651	1	1.24	4	15.46	7	0.61	8	14.32	8
3	17.50	10	14.35	2	3.15	15	0.41	15	15.92	5	0.75	4	15.84	4
4	16.29	12	5.90	14	10.39	4	1.44	1	11.09	13	0.28	13	9.80	13
5	18.37	9	11.60	5	6.77	11	0.83	13	14.98	8	0.63	7	14.59	7
6	22.49	2	11.36	6	11.33	3	1.24	5	16.92	2	0.76	3	15.98	3
7	11.42	15	7.00	12	4.42	14	0.87	9	9.21	14	0.23	14	8.94	14
8	20.36	4	11.35	7	9.28	5	1.02	7	15.99	4	0.70	6	15.30	6
9	11.97	14	5.88	15	6.09	13	1.15	6	8.92	15	0.21	15	8.38	15
10	15.98	13	6.92	13	9.06	6	1.28	3	11.45	12	0.33	12	10.51	12
11	20.63	5	12.73	3	7.90	9	0.87	10	16.68	3	0.78	2	16.20	2
12	18.87	7	7.50	11	11.37	2	1.36	2	13.18	11	0.42	11	11.89	11
13	24.01	1	15.07	1	8.94	7	0.84	12	19.45	1	1.08	1	19.02	1
14	18.69	8	10.43	8	8.26	8	1.00	8	14.56	9	0.58	9	13.96	9
15	19.32	6	12.40	4	6.92	10	0.81	14	15.86	6	0.71	5	15.47	5

GMP: Geometric Mean Productivity, STI: Stress Tolerance Index, MP: Mean Productivity, SSI: Susceptibility Stress Index, DI: Drought Index, RDI: Relative Drought Index, TOL: Tolerance index, Y_P: Yield potential and Y_S: Yield stability

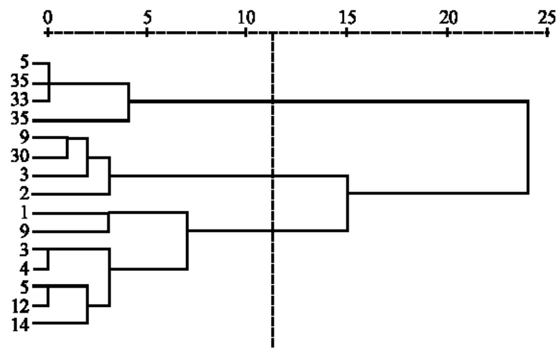

Fig. 1: Cluster analysis in red bean under the non stress condition

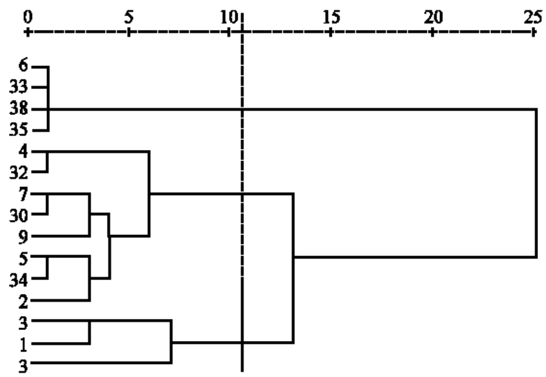

Fig. 2: Cluster analysis in red bean under the stress condition

condition is firstly for leaf dry weight and 100 seed weight, so this reduction in aerial organs is caused yield reduction. This finding has been shown in Hayse and Singh (2007), German *et al.* (2006) and Singh (2007) researches. In simple correlation in non-stress condition a lot of traits are significant, which shows common factors maybe exist. In factors analysis the genotypes selection was done due to the first and second factors that were that most important factors. In both stress and non-stress condition the genotype 3 was selected, that is confirmed in the previous researches such as German *et al.* (2006).

DISCUSSION

Several hundred breeding lines and cultivars of common bean of diverse origins from the centers of origin and domestication of the crop in Latin America were systematically screened for drought resistance (Laing *et al.*, 1983; Singh *et al.*, 2003). However, as reported in this study, the highest level of drought resistance was found in race Durango cultivars from the Mexican highlands. Acosta-Gallegos and Adams (1991), Boutraa and Sanders (2002) and Beebe *et al.* (2008) also reported high levels of drought resistance among cultivars. In this study, we attempt to evaluate the effect of water stress (limited irrigation) on different traits of bean. Breeding crops for drought resistance is often considered to be a slow and difficult process (Singh *et al.*, 2007). For dryland or rain-fed environments, weather fluctuations, primarily the amount, duration, frequency and timing of rainfall in relation to crop growth stages, are primary determinants of the levels of terminal or intermittent drought stress. Significant variation for these seasonal factors and their interaction with genotypes, complicate the selection process in field-grown nurseries (Beebe *et al.*, 2008). Therefore, for development of nine drought resistant lines, the F_2 to F_7 were grown under NS environment. The F_{5-8} lines were evaluated in replicated yield trials for 3 yr in both DS and NS environments (Singh, 1995). Similarly, in this study, it was essential to conduct replicated trials for four cropping seasons in DS and NS environments to obtain reliable estimates for the three traits. Significant interactions among genotypes, cropping seasons and DS versus NS environments occurred for most traits including seed yield. Moreover, drought at CIAT-Palmira may not be representative of that occurring in the major drought endemic regions of the world (Abebe *et al.*, 1998; Miller and Burke, 1983; Rosales-Serna *et al.*, 2004). Thus, common bean genotypes identified or selected at CIAT-Palmira, Colombia, would need to be tested locally under drought stress before use in research and production programs elsewhere.

As a conclusion, the direct effects of 100-seed weight, seed number per bush in stress condition was very high, but indirect effects showed a weak consequence. As a result a direct selection is suggested for these traits. Direct effects of day's number till the leaves appearance was less considerable in compare with two previous traits. Also indirect effects were unwanted. In resistance amount studying, indirect effects of tolerance's susceptibility and also traits changes percentage in stress conditions were measured. Geometric Mean Productivity (GMP), Stress Tolerance Index (STI) and Mean Productivity (MP) were the most suitable indicators for selecting drought resistant genotypes. Based on these indicators KS-31146 and KS-31150 in red beans, were found as resistant genotypes (Table 7).

Table 7: Selected genotypes base Indices of interest

Selection base on	Selected genotypes
Y_P	13, 6, 2, 8,11
Y_S	13, 3, 11, 15, 5
TOL	3, 7, 9, 1, 5
SSI	3, 15, 5, 13, 1
MP	13, 6, 11, 8, 3
STI	13, 11, 6, 3, 15
GMP	13, 11, 6, 3, 15

GMP: Geometric Mean Productivity, STI: Stress Tolerance Index, MP: Mean Productivity, SSI: Susceptibility Stress Index, DI: Drought Index, RDI: Relative Drought Index, TOL: Tolerance index, Y_P: Yield potential and Y_S: Yield stability

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