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# INFLUENCE OF DROUGHT ON SEED YIELD COMPONENTS IN COMMON BEAN

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**Summary**. The effect of drought on the seed yield components: pod number per plant, seed number per pod, 100-seed weight (g) in bean *Phaseolus vulgaris* populations P1, P2, F1, F2, BC1, BC 2 and the heritability of these traits were evaluated. We included in this study six parents (five local cultivars and one French cultivar); F332, Ami, Ardeleana, Aversa, Star, EO2 and five hybrid combinations for each population. The 26 genotypes were evaluated in natural drought – stressed (2000 year) and nonstressed (1999 year) environments, at the Research Institute for Cereals and Industrial Crops Fundulea, Romania. Drought stress determined by the drought intensity index (DII) was severe (0.80). Drought stress reduced seed yield by 80%, pods number per plant by 60%, seeds number per pod by 26%, 100-seed weight by 13%. Yield under drought stressed (DS) was correlated with yield under nonstressed (NS) environments and negatively correlated with the drought suseptibility index and with the percent reduction (PR).

Heritability estimates for seed yield components ranged from 0.59 to 0.13 in nonstressed (1999) and from 0.48 to 0.11 in drought stressed environments (2000).

***Key words*****:** Common bean, *Phaseolus vulgaris* drought stress, drought susceptibility index, drought intensity index, geometric media, percent reduction, heritability.

## Introduction

Drought stress is a worldwide production constraint of common bean (Fairbairn, 1993; Wortmann et al., 1998; quoted by Teran and Singh, 2002).

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In Romania the largest areas cultivated with bean are situated in the country's south and south-east, where drought is very frequent. Prolonged drought, occuring during the flowering and grain filling periods (June–August), which generally are enhanced by heat and low air relative moisture, are the most damaging for bean.

This type of drought causes an increased frequency of barren plants and incomplete seed setting. The 2000 year in Romanian conditions was dry, with uninterrupted drought from May to September, the sum of rainafall on the vegetation season (May, June, July, August) at Research Institute Fundulea was only 94.6 mm. The 1999 year had a favourable pluviometric regime for bean growth (the sum of rainfall was 339.6 mm in May–August).

Water stress during the flowering and grain filling periods reduced seed yield and seed weight and accelerated maturity of dry bean (Singh, 1995).

Before developing a breeding program for any trait it is essential to determine extant genetic variability and the way for hereditary transmission. The highest levels of drought resistance are found in the tepary bean, *P. acutifolius* A. Gray (T.-Y. Lin and A. H. Markhart, 1996). Despite repeated efforts of successful interspecific hybridation, the use of tepary germoplasm for common bean improvement is limited. (Andrade-Aguilar and Jackson, 1988). Rosales-Serna et al. (2000) and Schneider et al. (1997) developed drought resistant lines using seed yield (GM geometric mean) and RAPD markers as selection criteria. Teran and Singh (2002) used geometric mean (GM), percent reduction (PR) and drought susceptibility index (DSI) for yield estimates of drought resistance. Similarly Ramirez-Vallejo and Kelly used geometric mean and drought susceptibility index to evaluate the association of specific phenological and physiological traits with resistance to drought in common bean.

The objectives of this study were to evaluate the effect of drought on the seed yield components (pods number/plant, seeds number/pod and 100-seed weight) in bean populations P1, P2, F1, F2, BC1, BC2; and to estimate heritability of these traits.

## Material and methods

This study was conducted during the 1999 and 2000 growing seasons at the Research Institute for Cereals and Industrial Crops Fundulea, Romania.

We included in this study six parents: F332, Ami, Ardeleana, Aversa, Star, E02 and five hybrid combinations for each populations; F1-1 = F332×Ami, F1-2 = F332×Ardeleana, F1-3 = F332×Aversa, F1-4 = F332×Star, F1-5 = F332×EO2; F2-1, F2-2, F2-3, F2-4, F2-5; BC1-1 = (F332×Ami)×F332; BC1-2 = (F332×Ardeleana)×F332, BC1-3 = (F332×Aversa)×F332, BC1-4 = (F332×Star)×F332, BC1-5 = (F332×EO2)×F332; BC2-1 = (F332×Ami)×Ami, B2-2 = (F332×Ardeleana)×Ardeleana, BC2-3 = (F332×Aversa)×Aversa, BC2-4 = (F332×Star)×Star, BC2-5 = (F332×EO2)×EO2.

**Table 1**. Characteristics of parents used in crosses

| Identification | Origin | Growth habit* | Maturity | Phenotypic seed color | Drought reaction** |
|---|---|---|---|---|---|
| F332 | ICCPT Fundulea –Romania | I | early | white | T |
| Ami | ICCPT Fundulea –Romania | III | early | white | S |
| Ardeleana | SCA Turda – Romania | I | late | white | S |
| Aversa | ICCPT Fundulea – Romania | III | late | white | S |
| Star | ICCPT Fundulea –Romania | II | late | white | MT |
| EO2 | France | I | early | white | S |

* I = determinate upright, II = indeterminate upright, III = indeterminate prostrate; ** T = tolerant, S = susceptible, MT = medium tolerant

The 26 genotypes were evaluated under natural drought stressed (2000 year) and nonstressed conditions (1999 year). The initial breeding material ( F1, F2, BC1, BC2) was achieved with cyclical and backcross hybridations in the 1997-1999 period , under greenhouse conditions. The populations (P1, P2, F1, F2, BC1, BC2) were studied in the field in 1999 and 2000 years, by ensuring 100 plants annually for each population. Sowing was done manually in the bean breeding field at distance 62.5 cm between rows, 6 cm between plants within rows and at a depth of 4–5 cm. The experimental design was random blocks, in three replications. Number of pods per plant, number of seeds per pod and 100-seeds weight were detrmined. Owing to unfavourable environmental conditions (prolonged drought with high temperatures), in 2000 year one irrigation with 300 $m^3$/ha was applied during the flowering period.

Drought susceptibility index for seed yield for each genotype was calculted as follows: DSI=[1–Ysd/Yns/DII,where Ysd and Yns are mean yields of a given each genotype in DS and NS environments, respectively (Fisher and Maurer, 1978); geometric mean (GM) was determined for seed yield, pod number/plant, seed number/pod and 100-seed weight, as GM = $(NS \times DS)^{1/2}$; half percent reduction (PR) due to drought stress in relation to the NS environment was also determined; the heritability coefficients in a broad sense was calculated with the formula proposed by Mahmud and Kramer, 1951 and in a narrow sense, with the formula proposed by Warmer, 1952. Relationship between different traits was determined with the multiple regression procedure.

## Results and Discussion

The drought stress in 2000 was very severe, indicated by the high drought intensity index (DII) value, 0.80 (Table 2). Seed yield of all genotypes in DS was significantly lower than in NS environment (Table 3).

**Table 2**. Mean growing season temperature, sum rainfall and drought intensity index for the two season cropping between 1999–2000, used to evaluate 26 common bean genotypes, ICCPT Fundulea, Romania.

| Year | Climatic factor | Month | | | | Drought intensity index* (DII) |
|---|---|---|---|---|---|---|
| | | May | June | July | August | |
| 1999 | Mean temperature, °C | 15,9 | 22,2 | 24,4 | 22,8 | 0,80 |
| | Sum rainfall, mm | 63,0 | 86,1 | 84,8 | 105,7 | |
| 2000 | Mean temperature, °C | 17,9 | 22,0 | 24,7 | 24,2 | |
| | Sum rainfall, mm | 33,0 | 25,0 | 26,3 | 10,3 | |

*DII = 1-Xds/Xns, where Xds and Xns, are the mean of genotypes in drought stressed and nonstressed environments, respectively.

On average the seed yield was reduced by 80%. The drought susceptibility index (DSI) for seed yield was high for all bean populations (mean 1.003).

The cultivars with the lowest DSI for yield were F 332 (0.915), Ami (0.925) and Star (0.958).

Seed yield in the DS environment was associated negatively with percent reduction (PR) and drought susceptibility index (DSI), mean for a higher yield was recorded lower PR and DSI values (Table 3). In Table 3 it can be observed that percent reduction (PR) in seed yield caused by water stress was associated positively with drought susceptibility index (DSI).

A positive correlation between seed yield in DS and NS environments supported similar findings by Ramirez-Vallejo and Kelly, 1998 and by Teran and Singh, 2002.

Genotypes that were high yielding in the NS – respectively Star, Ami and Aversa cultivars were also high yielding in DS environment ($r = 0.840^{***}$) (Fig. 1).

Among the parents used in crosses, Star exhibited the highest yield in both DS and NS environments and Ardeleana had the lowest yield in both conditions (Table 3).

High drought stress significantly reduced pods number per plant and lower seed number per pod and 100-seed weight in all bean combinations (Table 3).

On mean the pod number per plant was reduced by 60%, seed number per pod by 26% and 100-seed weight by 13%, this suggest that reduction of seed yield in drought stressed environment due mainly of pods number per plant. In the nonstressed environment the same trait is the most imporatnt for seed yield in common bean (Paulo Renalli, 1990).

Percent reduction (PR) was negatively associated with 100-seed weight, $r = -0.338$ NS (Fig. 2), seeds number per pod, $r = -0.786^{000}$ (Fig. 3) and pods number per plant, $r = -0.989^{000}$ (Fig. 4) in the DS environment.

Geometric mean (GM) was significantly associated with 100-seed weight, $r = 0.783^{***}$ (Fig. 5), seed number per pod, $r = 0.765^{***}$ (Fig. 6) and pod number per plant, $r = 0.990^{***}$ (Fig. 7).

Heritability in the broad sense (HL) and the narrow sense (HS) was slightly higher under nonstressed compared with drought stressed environment for all traits in all

Table 3. Pod number per plant, seed number per pod, 100-seed weight and mean yield for 26 common bean genotypes evaluated in drought-stressed and nonstressed environment at ICCPT Fundulea, Romania, in 2 cropping seasons: 1999, 2000.

| Genotype | Number of pods per plant, no. | | | | Number of seeds per pod, no. | | | | 100-seeds weight, g | | | | Seed yield, kg/ha$^{-1}$ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NS | DS | GM | PR, % | NS | DS | GM | PR, % | NS | DS | GM | PR, % | NS | DS | GM | PR, % | DSI |
| Parents | | | | | | | | | | | | | | | | | |
| F332 | 14.3 | 4.3 | 7.8 | 70 | 3.0 | 2.3 | 2.3 | 23 | 26 | 24 | 25 | 8 | 1454 | 386 | 749 | 73 | 0.915 |
| Ami | 16.2 | 7.8 | 11.2 | 51 | 3.2 | 3.0 | 3.0 | 6 | 28 | 26 | 27 | 7 | 2511 | 651 | 1278 | 74 | 0.925 |
| Ardeleana | 15.0 | 3.3 | 7.0 | 78 | 3.1 | 2.1 | 2.5 | 32 | 17 | 14 | 15 | 18 | 1139 | 122 | 372 | 89 | 1.116 |
| Aversa | 16.1 | 7.0 | 10.6 | 57 | 3.3 | 2.4 | 2.8 | 27 | 35 | 32 | 33 | 9 | 2840 | 633 | 1340 | 78 | 0.971 |
| Star | 17.2 | 9.0 | 12.4 | 48 | 3.5 | 2.4 | 2.8 | 31 | 26 | 20 | 23 | 23 | 2955 | 690 | 1427 | 76 | 0.958 |
| EO2 | 14.6 | 4.7 | 8.2 | 68 | 3.3 | 2.6 | 2.9 | 21 | 31 | 27 | 28 | 13 | 2351 | 495 | 1078 | 79 | 0.986 |
| Mean | 15.5 | 6.0 | 9.6 | 62 | 3.2 | 2.4 | 2.7 | 23 | 27 | 23 | 25 | 13 | 2208 | 496 | 1041 | 78 | 0.995 |
| F1 | | | | | | | | | | | | | | | | | |
| F332xAmi | 15.7 | 7.5 | 10.8 | 52 | 3.2 | 2.6 | 2.8 | 19 | 27 | 26 | 26 | 4 | 2297 | 582 | 1156 | 75 | 0.933 |
| F332xArdeleana | 14.9 | 4.0 | 7.7 | 73 | 3.1 | 2.3 | 2.6 | 25 | 23 | 20 | 21 | 13 | 1734 | 299 | 720 | 83 | 1.034 |
| F332xAversa | 15.5 | 6.9 | 10.3 | 55 | 3.3 | 2.5 | 2.8 | 24 | 33 | 25 | 29 | 24 | 2660 | 489 | 1140 | 82 | 1.020 |
| F332xStar | 16.8 | 8.8 | 12.1 | 48 | 3.4 | 2.5 | 2.9 | 26 | 26 | 21 | 23 | 19 | 2477 | 414 | 1013 | 83 | 1.041 |
| F332xEO2 | 14.5 | 4.5 | 8.0 | 69 | 3.2 | 2.6 | 2.8 | 19 | 28 | 26 | 27 | 7 | 1950 | 453 | 940 | 77 | 0.959 |
| *Mean* | *15.4* | *6.3* | *9.8* | *59* | *3.2* | *2.5* | *2.7* | *23* | *27* | *24* | *25* | *14* | *2224* | *447* | *994* | *80* | *0.997* |
| F2 | | | | | | | | | | | | | | | | | |
| F332xAmi | 15.2 | 7.2 | 10.4 | 53 | 3.1 | 2.5 | 2.7 | 19 | 27 | 26 | 26 | 4 | 2196 | 528 | 1077 | 76 | 0.949 |
| F332xArdeleana | 14.5 | 3.9 | 7.5 | 73 | 3.0 | 2.1 | 2.5 | 30 | 24 | 21 | 22 | 13 | 1714 | 273 | 684 | 84 | 1.050 |
| F332xAversa | 15.0 | 6.5 | 9.8 | 57 | 3.0 | 2.3 | 2.6 | 23 | 30 | 28 | 29 | 18 | 2310 | 471 | 1043 | 80 | 0.995 |
| F332xStar | 15.8 | 8.0 | 11.2 | 49 | 3.2 | 2.4 | 2.7 | 25 | 25 | 22 | 23 | 12 | 2156 | 414 | 945 | 81 | 1.009 |
| F332xEO2 | 14.4 | 4.0 | 7.5 | 72 | 3.1 | 2.4 | 2.7 | 22 | 32 | 29 | 30 | 9 | 1936 | 435 | 918 | 78 | 0.969 |
| *Mean* | *14.9* | *5.9* | *9.2* | *61* | *3.0* | *2.3* | *2.6* | *24* | *28* | *25* | *26* | *11* | *2062* | *424* | *933* | *79* | *0.994* |

| | NS | DS | GM | PR, % | NS | DS | GM | PR, % | NS | DS | GM | PR, % | NS | DS | GM | PR, % | DSI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BC1 | | | | | | | | | | | | | | | | | |
| (F332xAmi) | 15.5 | 6.8 | 10.2 | 56 | 3.1 | 2.4 | 2.7 | 23 | 26 | 23 | 24 | 12 | 2119 | 420 | 943 | 80 | 1.002 |
| (F332xArd.) xF332 | 14.4 | 4.2 | 7.7 | 71 | 3.1 | 2.0 | 2.4 | 35 | 22 | 21 | 21 | 5 | 1704 | 237 | 635 | 86 | 1.076 |
| (F332xAversa) xF332 | 14.9 | 7.0 | 10.2 | 53 | 3.1 | 2.2 | 2.6 | 29 | 30 | 27 | 28 | 10 | 2241 | 465 | 1021 | 79 | 0.990 |
| (F332xStar) xF332 | 15.0 | 7.5 | 10.6 | 50 | 3.3 | 2.3 | 2.7 | 30 | 26 | 23 | 24 | 12 | 2146 | 399 | 925 | 81 | 1.075 |
| (F332xEO2) xF332 | 14.3 | 4.3 | 7.8 | 70 | 3.2 | 2.4 | 2.8 | 25 | 29 | 27 | 27 | 7 | 1912 | 483 | 961 | 75 | 0.934 |
| *Mean* | *14.8* | *6.0* | *9.3* | *60* | *3.1* | *2.2* | *2.6* | *28* | *27* | *25* | *26* | *9* | *2024* | *401* | *897* | *80* | *1.015* |
| BC2 | | | | | | | | | | | | | | | | | |
| (F332xAmi) xAmi | 16.0 | 7.7 | 11.0 | 52 | 3.8 | 2.4 | 3.0 | 37 | 27 | 24 | 25 | 11 | 2347 | 496 | 1079 | 79 | 0.985 |
| (F332xArd.) xArdeleana | 15.0 | 4.5 | 8.2 | 70 | 3.2 | 2.2 | 2.6 | 31 | 18 | 15 | 16 | 17 | 1420 | 240 | 584 | 83 | 1.038 |
| (F332xAversa) xAversa | 16.0 | 7.2 | 10.7 | 55 | 3.3 | 2.4 | 2.8 | 27 | 36 | 29 | 32 | 19 | 2788 | 573 | 1264 | 79 | 0.993 |
| (F332xStar) xStar | 17.1 | 8.9 | 12.3 | 48 | 3.5 | 2.4 | 2.8 | 31 | 26 | 21 | 23 | 19 | 2768 | 435 | 1097 | 84 | 1.045 |
| (F332xEO2) xEO2 | 14.5 | 4.6 | 8.1 | 68 | 3.3 | 2.3 | 2.7 | 30 | 32 | 26 | 29 | 18 | 2256 | 429 | 984 | 81 | 1.012 |
| *Mean* | *15.7* | *6.5* | *10.0* | *59* | *3.4* | *2.3* | *2.8* | *31* | *28* | *23* | *27* | *17* | *2316* | *435* | *1002* | *81* | *1.014* |
| Overall mean | 15.2 | 6.1 | 9.5 | 60 | 3.1 | 2.3 | 2.7 | 26 | 27 | 24 | 26 | 13 | 2167 | 441 | 973 | 80 | 1.003 |
| LSD 5 % | 0.4 | 0.2 | 0.5 | 1.2 | 0.2 | 0.2 | 0.1 | 3.1 | 0.6 | 0.8 | 0.7 | 2.6 | 105.8 | 29.4 | 31.3 | 1.05 | 0.03 |

NS = nonstressed (1999 year), DS = drought stressed (2000 year) PR = percent reduction in the DS and NS environment, GM (geometric mean) = $(NS \times DS)^{1/2}$ and DSI (drought susceptibility index) = (1 – Yds / Yns)/ DII, where Yds and Yns are mean yield of a given genotype in DS and NS environments respectively. Ard. = Ardeleana

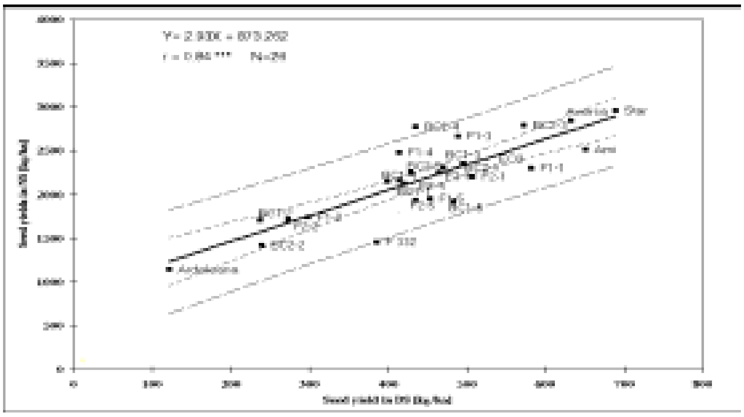

**Fig. 1**. Relationships between seed yield in nonstressed (NS) – 1999 and seed yield in drought stressed – 2000 environments – ICCPT Fundulea, Romania.

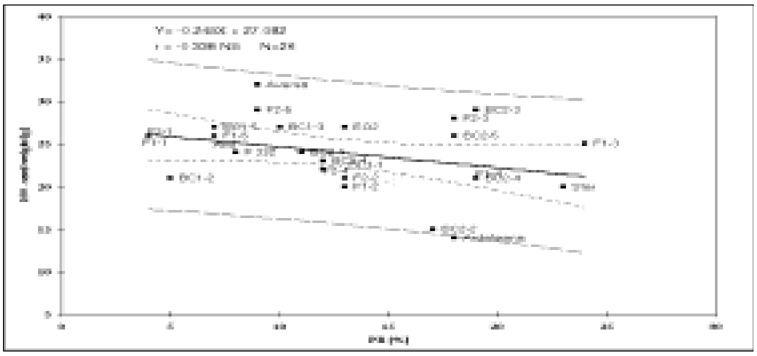

**Fig. 2**. Relationships between 100-seed weight in DS and percent reduction (PR) - ICCPT Fundulea, Romania

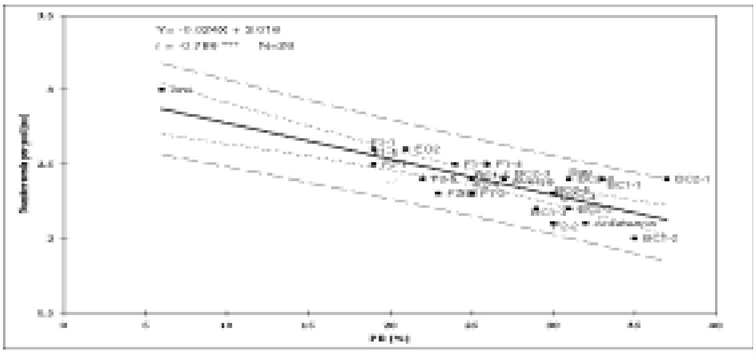

**Fig. 3** Relationships between number of seeds per pod in DS and percent reduction (PR) – ICCPT Fundulea, Romania

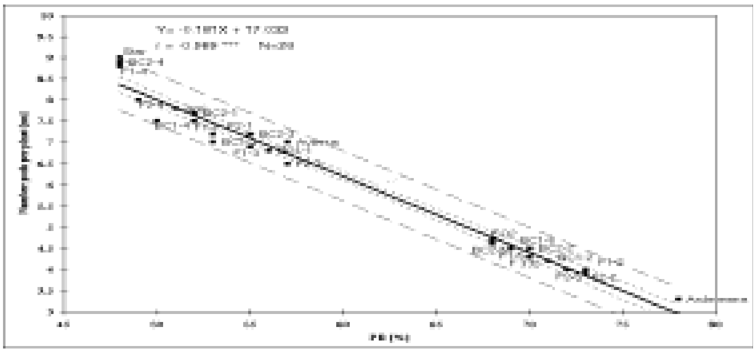

**Fig. 4** Relationships between number of pods per plant in DS and percent reduction (PR) – ICCPT Fundulea, Romania

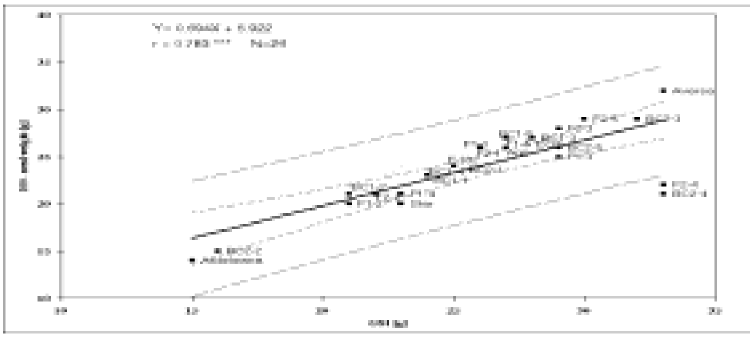

**Fig. 5**. Relationships between 100-seed weight in DS and geometric mean (GM) - ICCPT Fundulea, Romania

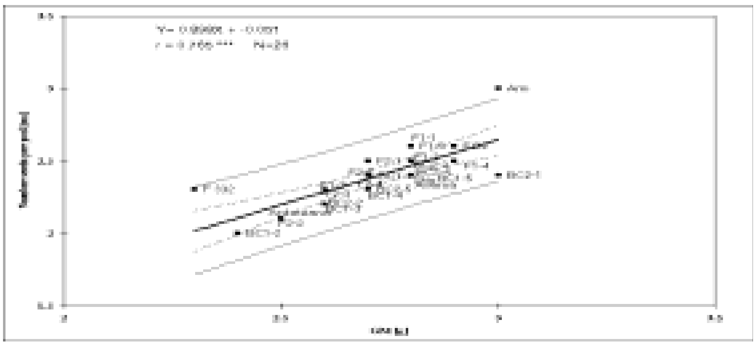

**Fig. 6**. Relationships between number of seeds per pod in DS and geometric mean (GM) – ICCPT Fundulea, Romania

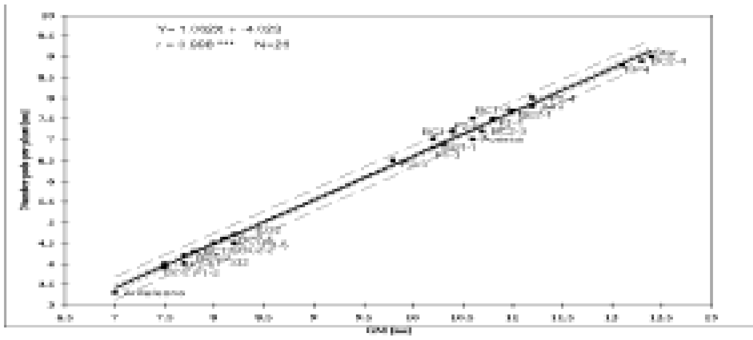

**Fig. 7**. Relationships between number of pods per plant in DS and geometric mean (GM) – ICCPT Fundulea, Romania

populations, except for pod number per plant in F332×Star combination for which the contrary occurred (Table 4).

In fact, the heritability in the broad sense (HL) and the narrow sense (HS) for yield and for seed yield components of common bean, under drought and nonstress environments were in generally similar. This suggests that selection should be equally effective under different levels of stress (White et all., 1994; Singh, 1995; Schneider et al., 1997).

Breeding crops for drought resistance is considered to be a slow and difficult process (Blum, 1988; Hurd, 1976; quoted by Singh, 2002).

The effect of drought is complex in its mode of action, highly variable in response, accentuated by interacting factors and localized within environmental regions.

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 (Ramirez-Vallejo & Kelly, 1998).

Dudley, 1982 and Urrea and Singh, 1995 suggest that a backcross conversion program may be required to introgress drought resistance from the resistant races into locally adapted cultivars, or a two or three stage selection strategy (Kelly at al., 1998; Singh, 2001).

The single-seed-descent (SSD) selection method (Brim, 1966) should be effective in improving water stress tolerance. The bulk method could be useful especially for drought endemic environments (Singh, 1995).

## Conclusions

Environmental conditions, namely drought stress, played an important role in phenotypic expression of seed yield components (pod number per plant, seed number per pod and 100-seed weight) of common bean. Pod number per plant, seed number per pod and 100-seed weight were significantly reduced in all populations by drought stress.

T**able 4**. Heritability for pod number per plant, seed number per pod, 100-seed weight and seed yield per plant (1999, 2000 years)

| Bean population | Heritability | | | |
|---|---|---|---|---|
| | HL | | HS | |
| | NS | DS | NS | DS |
| | Pods number per plant | | | |
| F332 x Ami | 0.40 | 0.32 | 0.23 | 0.18 |
| F332 x Ardeleana | 0.31 | 0.28 | 0.20 | 0.16 |
| F332 x Aversa | 0.36 | 0.30 | 0.18 | 0.15 |
| F332 x Star | 0.41 | 0.36 | 0.14 | 0.19 |
| F332 x EO2 | 0.59 | 0.48 | 0.32 | 0.25 |
| | Seeds number per pod | | | |
| F332 x Ami | 0.31 | 0.27 | 0.28 | 0.25 |
| F332 x Ardeleana | 0.48 | 0.43 | 0.26 | 0.21 |
| F332 x Aversa | 0.43 | 0.38 | 0.30 | 0.27 |
| F332 x Star | 0.29 | 0.25 | 0.23 | 0.19 |
| F332 x EO2 | 0.45 | 0.42 | 0.35 | 0.30 |
| | 100-seed weight | | | |
| F332 x Ami | 0.31 | 0.28 | 0.12 | 0.11 |
| F332 x Ardeleana | 0.33 | 0.31 | 0.13 | 0.10 |
| F332 x Aversa | 0.21 | 0.20 | 0.16 | 0.14 |
| F332 x Star | 0.13 | 0.15 | 0.10 | 0.13 |
| F332 x EO2 | 0.18 | 0.17 | 0.15 | 0.14 |
| | Seed yield per plant | | | |
| F332 x Ami | 0.34 | 0.38 | 0.20 | 0.19 |
| F332 x Ardeleana | 0.42 | 0.40 | 0.15 | 0.14 |
| F332 x Aversa | 0.26 | 0.22 | 0.14 | 0.13 |
| F332 x Star | 0.36 | 0.35 | 0.18 | 0.17 |
| F332 x EO2 | 0.24 | 0.21 | 0.17 | 0.15 |

NS = nonstressed (1999 year), DS = drought stressed (2000 year), HL( broad sense heritability) = $V_G / V_{F2}$ , where $V_G$ – genetic variance and $V_{F2}$ – all variance ($F_2$) HS (narrow sense heritability) = $V_A / V_{F2,}$ where $V_A$ – additive variance

Because of a positive association between percent reduction (PR) and drought susceptibility index (DSI) for seed yield, either trait could be used in combinations with the geometric mean yield (GM) to select drought resistant genotypes.

The low values of heritability in a broad sense and in a narrow sense in both DS and NS environments indicated medium chances of transmitting to the offspring the traits that determine bean productivity and improvement for these traits .

High drought stress reduced significantly the yield for all 26 genotypes (cultivars and hybrid combinations), which suggests that genetic variability for drought resistance in *Phaseolus vulgaris* is low. When drought stress is very severe as in 2000 in the south-east of Romania, common bean growth without irrigation, was compromised by 100%.

With a careful selection for parents used in hybridization and with the application of an adequate selection method for maximum genetic gain it should be possible to obtain inbred resistant lines of a moderate drought.

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