# Response of common bean cultivars and lines to water stress

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## ABSTRACT

Water stress tolerance was assessed in three cultivars and seven lines of cammon bean (*Phaseolus vulgaris* L.) belonging to the commercial black and carioca groups. Two independent experiments, one for each group, were set up in Londrina in the year 2000 wet season. A randomized complete block design was used with splitplots and three replications. The plots consisted of treatments with and without water stress and the splitplots of cultivars and lines. Grain yield and grain yield components were assessed. There was genetic variability among the cultivars and lines, as detected by the estimates of the genetic, environmental variation coefficients and B index. Water stress reduced grain yield by, approximately, 50%, but the IPR88 Uirapuru cultivar, from the black commercial group, and the LP 97-13 and LP 97-4 lines from the carioca commercial group stood out as drought tolerant and showed with high yield potential.

KEY WORDS: *Phaseolus vulgaris*, drought resistance, genetic variability.

## INTRODUCTION

The common bean (*Phaseolus vulgaris* L.) species is not very tolerant to severe water stress. About 60% of the yield loss is reported from drought, making it second only to disease as a grain yield reducer. Some management practices, like irrigation, can contribute to the increase of grain yield under water stress conditions, thus the development of tolerant cultivars becomes an efficient and economical production strategy (White et al. 1994; Singh, 1995).

Hall (1993) defines drought as the relative yield of a genotype compared to other genotypes submitted to the same water stress. Susceptibility to drought is frequently measured by reduction in grain yield, but the values are frequently confused with the potential genotype yields (Blum, 1988). Drought tolerance implies the ability to sustain reasonable yields under moderate water stress, and not the ability to survive over prolonged and severe water stress periods (Mariot, 1989).

Studies to evaluate common bean performance under water stress conditions have been carried out, by assessing the morphological, physiological and biochemical characteristics associated with tolerance (Acosta-Gallegos, 1988). Blum (1997) recommended the use of parameters correlated with crop grain yield which are easy to measure, instead of assessments such as proline, glycine-betain and deidrine accumulation, which are hard to measure.

Water stress reduces the expression of many characteristics, except days to flowering and moisture retention in the leaf (Ramirez-Vallejo and Kelly, 1998). Singh (1995) observed a decrease in grain yield and mean weight of a hundred seeds along with accelerated maturity among these characteristics.

Periods of water stress during the reproductive phase of the common bean cause significant reduction in grain yield (Pimentel et al., 1999; Nielsen and Nelson, 1998; Ramirez-Vallejo and Kelly, 1998; Oliveira and Faria, 1996; Raggi et al., 1972). Dubetz and Mahlle (1969) found grain yield reduction of 53%, 71% and 35% when water stress occurred in the pre-flowering, flowering and post flowering stages, respectively. The decrease in grain yield results from a low percentage of fruit production from flowers when drought occurs during flowering, and from embryos abortion when it occurs in the pod-forming stage (Parjer, 1976). Cultivar grain yield decreased as the number of

days of stress increased during the drought resistance assessment studies. Decreases in grain yield of up to 20% were observed when cropping went up to 14 days without irrigation during flowering (Silveira et al. 1981). After 17 and 20 days without irrigation, the decreases in grain yield were, respectively, 30% and 52% (Magalhães and Millar, 1978). Common bean cultivars and lines respond differently to water stress in the soil during the flowering period depending on the magnitude of the water stress (Karamanos and Papatheohari, 1999; Singh, 1995; Schneider et al., 1997).

The present study assessed reaction to water stress in three cultivars and seven promising lines, from the Paraná Agronomic Institute - IAPAR -breeding program. The most tolerants will be selected for registration in Parana state and to be used as parents in plant breeding.

## MATERIAL AND METHODS

### Genetic material

Reaction to water stress was assessed in three cultivars and seven lines of common bean in two independent experiments, one for each commercial color group. Three lines from the black group (LP 98-1, LP 98-11 and LP 98-13) and cultivars FT Nobre and IPR88 Uirapuru were assessed. The cultivar IPR88 Uirapuru was registered recently for cultivation in the state of Paraná and classified as moderately tolerant to water stress (Moda-Crino et al., 2001). Lines LP 97-4, LP 97-13, LP 97-23, LP 97-28 and the Carioca cultivar were also assessed in the carioca group. The FT Nobre and the Carioca cultivars were used as controls for grain yield in their respective groups. All lines and cultivars showed a Type II undetermined growth pattern, except the Carioca cultivar which showed a Type III indetermined growth pattern.

### Performing the experiments

The experiments were carried out at the Experimental Station of the Agronomic Institute of Paraná State (IAPAR) in Londrina – PR, in 2000/2001 in the wet season, under two conditions: with and without water stress.

The experiments were set up in three frames with concrete sides measuring 10m long by 5m wide and 1m deep. The area soil is classified as dystrophic Purple Latossoil, whose physical and moisture characteristics have been described by Faria and Madramootoo (1996).

A randomized complete block design was used with split plots and three replications. The plots constituted treatments with and without water stress and the cultivars and lines constituted the split plots. The split plots contained four 5m lines, spaced at 0.5m, and sowing density with 20 viable seeds per meter. They were thinned after emergence, and 15 plants per meter remained. Assessments were carried out in the split plots two central lines.

The black group was sown on 21 September 2000 and the carioca group was sown on 17 October of the same year, both using conventional methods and a hand sowing machine.

250kg/ha 4-30-10 N – $P_2O_5$ – $K_2O$ of basic fertilizer was applied during sowing according to the chemical analysis of the soil. Twenty-two days after emergence, side-dressing nitrogen fertilizer, 200kg/ha ammonia sulphate, was applied.

Weeds, pests and diseases were controlled with chemical products except for common bacterial blight, as there is no efficient chemical control for this disease.

All plots were spray irrigated until flowering on set (R6 development stage - CIAT 1987). Irrigation was stopped for 20 days in plots submitted to water stress. Plots were protected from rain with mobile shelters with a pulley system that slid on iron rails attached to the sides of the frames. Shelters were built in iron with transparent polyethylene tops and sides, 10m long by 5m wide by 2.8m high.
During the water stress period, soil moisture was determined by the gravimetric method for the 0-10cm depth, and a neutron probe for the 10-25cm and 25-40cm depths. Measurements were taken twice a week in treatments with and without water stress. Water storage in the soil was calculated in the 0-40cm profile from these data.

### Assessing traits

Ten plants were randomly sampled at the R9 physiological maturity stage (CIAT, 1987) from the useful area of each split plot, and the following parameters were assessed:

NN: number of nodes on the main stem, measured from the cotyledonal node to the last productive node;

AP: plant height (main stem length in cm), measured from the cotyledonal node to the height of the last leaf;

VP: number of pods per plant;

SV: number of seeds per pod;

PCS: mean weight of 100 seeds (g);

PP: grain yield per plant (g);

PT: total grain yield (kg/ha),

where the PCS, PP e PT characteristics were quantified at 13% of grain umidity.

### Data Analysis

Data was statistically analyzed by the GENES program (Cruz, 1997) considering the stress and genotype effects as fixed. The estimates of the genetic quadratic components, the genetic (CVg%) and environmental (CVe%) variation coefficients and the B indexes were calculated by the following expressions:

**Genetic quadratic component:**

$$\phi g = \frac{QMG - QMEb}{rp}$$

**Genetic variation coefficient:**

$$CVg = \frac{(\phi g)^{1/2}}{m} \times 100$$

**Environmental variation coefficient:**

$$CVe = \frac{\{100 \times (QMEb)^{1/2}\}}{m}$$

B index:

$$\frac{CVg}{CVe} \times 100$$

The GENES program (Cruz, 1997) supplied all the phenotypic correlation matrixes. The significance of these correlations was tested by the t test with n-2 degrees of freedom at 5% and 1% probability (Steel and Torrie, 1960).

A reduction index (IR) was obtained for all cultivar and lines to show the effect of water stress on the assessed characters, by the expression:

$$IR\% = \frac{\text{Without stress} - \text{With stress}}{\text{Without stress}} \times 100$$

### RESULTS AND DISCUSSION

Water suppression during flowering stages and the beginning of pod development reduced most of the characteristics assessed, showing the susceptibility of the common bean cultivar and lines to water stress at this stage of development. These results were confirmed by Pimentel et al. (1999), Nielsen and Nelson (1998), Ramirez-Vallejo and Kelly (1998), Oliveira and Faria 1996, Raggi et al. (1972) and Dubetz and Mahlle (1969).

Figure 1 shows the soil water storage in the 0-40cm layer during the water stress period. In both groups, water stress occurred under the stress treatment, and its absence was observed under the non-stress treatment. Water storage in the soil varied from approximately 70mm to 10mm in the treatment with stress, and the permanent wilting point was situated below 10mm water in the profile of this soil. In the treatment without stress, most of the points on the curve are above 50% available water in the soil, coming close to field capacity, calculated at 140mm water for this profile in this soil. According to Gallegos and Shibata (1989), the bean crop yield is not affected when the available water in the soil is kept above 50%.

### Analysis of variance and estimates

In the commercial black group (Table 1) the effect of the genotypes was significant at 1% of probability for the AP, SV and PCS traits, at 5% for the PP trait, and non significant for NN, VP and PT traits. The significant effect of the genotypes indicates how much the variation observed results from genetic differences. The stress effect was significant at 1% of probability for all the characteristics assessed, except for AP. Stress x genotypes interaction was significant only for AP, which means that, for this characteristic, the cultivars and lines behaved differently from expected.

The greatest genetic variation coefficient (CVg) occurred with PP (16,4%) and the least with PT (0,7%). The environmental variation coefficient (CVe) of the experiment, which measures the random variation compared to the general mean, varied from 3.5% for AP to 14,3% for PP. The B
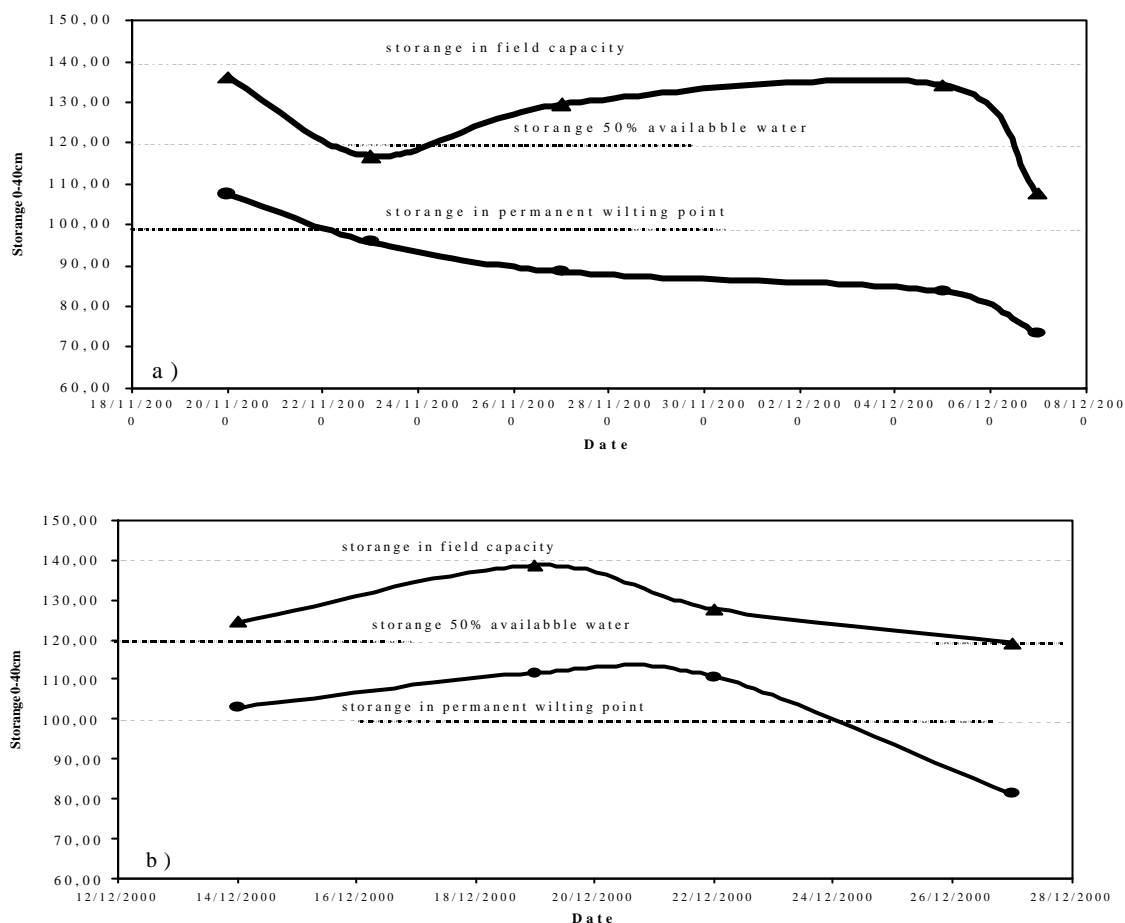
**Figure 1** - Water storage in the 0-40cm profile in the dystrophic Purple Latossoil, for common bean cultivars and lines belonging to the commercial black (a) and carioca (b) groups with (inferior curve) and without (superior curve) water stress.

index, which gives an indication of the genetic variability of a trait, without influencing its general mean, varied from 5.6% for PT and 292.1% for PCS. According to Vencovsky and Barriga (1992), B values over 100% indicate a very favorable situation for selection, and the genotypic effect is very significant as found in AP, SV, PCS and PP. When the genotypic effect is not significant, a low B index, low CVg% and high CVe% are expected. The general means for the traits within this group can also be observed in Table 1.

In the commercial carioca group (Table 1) the genotypic effect was significant at 1% of probability for the NN, AP, PCS and PT traits, but non significant for VP, SV or PP. The effect of stress was significant at 1% probability for VP and PT; significant at 5% for NN, PCS and PP and not significant for AP and SV. The stress x genotype interaction was not significant for any of the traits assessed in the carioca group, showing that all the assessed cultivars and lines responded uniformly to the stress level used.

The greatest CVg was observed with the PT trait (17.6%) and the least with the SV (3.7%). The environmental variation coefficient of the experiment varied from 4.0% for PCS to 25.7% for PP. The greatest B indexes occurred with NN (156.9%) and PCS (317.5%) indicating a favorable situation for selection. The CVg%, CVe% and B index estimates indicated the presence of genetic variability among cultivars and lines for all the characteristics, in both groups, except for the VP trait in the commercial carioca group, where the stress effect was high and the genetic expression low. Table 1 shows the general means for the traits in this group and the sharp reduction in total grain yield under the effect of water stress.

**Phenotypic correlation**

Table 2 shows the phenotypic correlations. In the commercial black group, PT correlated negatively with NN ($-0,847^{/2}$) and AP ($-0,874^{/2}$); VP with AP ($-0,806$) and PCS with VP ($-0,648$).

Negative and significant correlations indicate that selection of a trait decreased the expression of another (Ramalho et al., 1993). The NN trait correlated positively with AP (0.804) and PP (0.715). VP showed positive and significant correlation with SV (0.775), which in turn correlated with PP (0.710).

In the commercial carioca group, the negative correlations were not statistically significant.

Among the positive and significant correlations were: NN with AP (0.705), VP (0.931) with PT (0,694); VP with PP (0,649) with PT (0,687); PP with PT (0.901) and PCS (0.863); and PT with PCS (0.592).

Knowledge of the correlation between traits permits assessment and association which inform the breeder of changes that occur in a determined trait due to selection on another correlated trait.

**Table 1** - Summary of the analyses of variance, genetic variation coefficients (CVg%), environmental variation coefficients (CVe%), B indexes (B%) and mean of seven traits assessed in cultivar and lines of the commercial black and carioca groups.

| FV | NN[3/] | AP | VP | SV | PCS | PP | PT |
|---|---|---|---|---|---|---|---|
| **Black group** | | | | | | | |
| stress | [2] | ns | [2] | [2] | [2] | [2] | [2] |
| genotypes | ns | [2] | ns | [2] | [2] | [1] | ns |
| interaction | ns | [2] | ns | ns | ns | ns | ns |
| CVg% | 5.6 | 6.4 | 7.4 | 8.1 | 11.1 | 16.4 | 0.7 |
| CVe% | 7.9 | 3.5 | 12.6 | 4.0 | 3.8 | 14.3 | 12.4 |
| B% | 70.9 | 182.8 | 58.7 | 202.5 | 292.1 | 114.7 | 5.6 |
| Means | 10.7 | 63.2 | 11.9 | 5.1 | 21.1 | 12.9 | 1852.4 |
| **Carioca group** | | | | | | | |
| stress | [1] | ns | [2] | ns | [1] | [1] | [2] |
| genotypes | [2] | [2] | ns | ns | [2] | ns | [2] |
| interaction | ns | ns | ns | ns | ns | ns | ns |
| CVg% | 9.1 | 9.9 | - | 3.7 | 12.7 | 11.3 | 17.6 |
| CVe% | 5.8 | 11.8 | 21.4 | 9.4 | 4.0 | 25.7 | 20.2 |
| B% | 156.9 | 83.9 | - | 39.4 | 317.5 | 44.0 | 87.1 |
| Means | 10.85 | 59.6 | 12.5 | 4.1 | 21.3 | 11.1 | 1353.7 |

[1/] Significant at 5% probability, ns: not significant;

[2/] Significant at 1% probability;

[3/] NN: number of nodes on the main stem; AP: plant height (main stem length in cm); VP: number of pods per plant; SV: number of seeds per pod; PCS: mean weight of 100 seeds (g); PP grain yield per plant (g); PT total grain yield (kg/ha).

## Classification of cultivars and lines by their water stress tolerance level

Table 3 shows the IR% (reduction indexes in percentage) caused by water stress for the commercial black and carioca groups.

The FT Nobre cultivar in the black group had lower IR% for NN, AP, VP, PCS and PP; and the IPR88 Uirapuru cultivar for SV and PT. In the carioca commercial group, the Carioca cultivar presented the lowest IR% for SV and PCS; LP 97-4 for NN and PT; and LP 97-13 for AP, VP and PP. The Carioca cultivar, differently from the results obtained

**Table 2** - Estimates of the phenotypic correlation for the traits assessed in common bean plant cultivars and lines of the black commercial group (upper diagonal) and commercial carioca group (lower diagonal).

| Character | NN [3] | AP | VP | SV | PP | PT | PCS |
|---|---|---|---|---|---|---|---|
| NN | | $0.804^{[2]}$ | 0.288 | 0.379 | $0.715^{[1]}$ | $-0.847^{[2]}$ | 0.387 |
| AP | $0.705^{[1]}$ | | $-0.806^{[2]}$ | 0.071 | 0.325 | $-0.874^{[2]}$ | -0.362 |
| VP | $0.931^{[2]}$ | 0.449 | | $0.775^{[2]}$ | 0.347 | -0.318 | $-0.648^{[1]}$ |
| SV | 0.086 | -0.173 | -0.030 | | $0.710^{[1]}$ | -0.200 | -0.287 |
| PP | 0.563 | 0.165 | $0.648^{[1]}$ | -0.284 | | -0.282 | 0.440 |
| PT | $0.694^{[1]}$ | 0.252 | $0.687^{[1]}$ | 0.365 | $0.901^{[2]}$ | | -0.022 |
| PCS | 0.307 | 0.214 | 0.385 | -0.454 | $0.863^{[2]}$ | $0.592^{[1]}$ | |

[1] significant at 5% probability, ns: not significant; [2] Significant at 1% probability; [3] NN: number of nodes on the main stem; AP: plant height (main stem length in cm); VP: number of pods per plant; SV: number of seeds per pod; PCS: mean weight of 100 seeds (g); PP grain yield per plant (g); PT total grain yield (kg/ha).

by Pimentel and Perez (2000), did not recover quickly after water stress. The FT Nobre cultivar and LP 98-11 and LP97-13 lines showed an increase in AP when submitted to water stress. Field observations confirm this result as some cultivars and lines are etiolated under the water stress effect.

More attention should be paid to cultivars and lines with the greatest PT and lowest IR% once they are more adapted to cultivation conditions where water stress is frequent. Thus Figure 2 shows the performance of the cultivars and lines assessed in the present study for PT and IR%. The classification of cultivars as drought tolerant or susceptible is given by the performance of each one, within its respective group (Hall, 1993).

In Figure 3, the median horizontal line of grain yield under water stress condition divides the cultivars and lines into two groups: above the line are those with high yield potential (I and II quadrants) and below the line, those with low potential (quadrants

II and IV). The median vertical line of the reduction index (IR%) also divides the cultivars and lines into two groups: on the left hand side are those with low IR% (quadrants I and IV) and on the right hand side, those with high IR% (quadrants II and III). Thus the cultivars and lines were classified into four categories: 1 - drought tolerant with high yield potential (quadrant I); 2 - low drought tolerance but with high yield potential (quadrant II); 3 - low drought tolerance with low yield potential (quadrant III); and 4 - tolerant to drought but with low yield potential (quadrant IV). This methodology enabled identification and selection of cultivars and lines with desirable characteristics.

The IPR88 Uirapuru cultivar excelled in the commercial black group and was classified as drought tolerant with high yield potential, confirming results previously obtained by Moda-Cirino et al. (2001). The other materials in the commercial black group, LP 98-1, LP 98-11, LP 98-13 and FT Nobre were classified as low

drought tolerant but with high yield potential. In the commercial Carioca group, the LP-97-4 and LP97-13 lines showed the greatest grain yields and the lowest IR% and were classified as drought tolerant with high yield potential. The LP 97-23 line, classified as drought tolerant but with low yield potential, presented superior performance to the LP 97-28 and the Carioca, classified as low drought tolerant, presented low yield potential. The data presented are in line with the experimental results obtained by other authors, who observed a sharp reduction in grain yields. The magnitude of these reductions depended on the cultivars and lines assessed (Karamanos and Papatheohari, 1999; Oliveira and Faria, 1996; Silveira et al., 1981; Magalhães and Millar, 1978).

The LP-98-1 and LP98-11 lines, in the commercial black group, and LP 97-4 and LP 97-13, in the commercial carioca group, will be selected for future registration for cultivation in the state of Paraná. Both the lines and cultivar, which excelled for water stress tolerance, can be used as parents in breeding programs to obtain superior cultivars with high yield potential and drought tolerance.

## CONCLUSIONS

Water suppression during flowering and the first stages of pod development reduced most of the characteristics assessed.

In the commercial black group, the IPR88 Uirapuru cultivar stood out and was classified as drought tolerant and with high yield potential. In the commercial carioca group ,the LP 97-4 and LP 97-13 lines showed the greatest grain yields and the lowest IR%, being classified as drought tolerant with high yield potential.

Significant phenotypic correlations found for some pairs of traits indicate the possibility of performing simultaneous selection among the traits assessed.

**Table 3** - Reduction indexes in percentage of seven characteristics assessed in common bean cultivars and lines belonging to the commercial black and carioca groups.

| genotypes | NN[1/] | AP | VP | SV | PCS | PP | PT |
|---|---|---|---|---|---|---|---|
| Commercial black group | | | | | | | |
| FT Nobre | 1.8 | -16.0 | 25.3 | 11.1 | 0.5 | 34.2 | 61.8 |
| Uirapuru | 12.9 | 4.7 | 47.5 | 10.2 | 5.4 | 56.4 | 48.3 |
| LP 98-1 | 14.1 | 0.7 | 39.1 | 20.7 | 4.7 | 50.0 | 57.9 |
| LP 98-11 | 10.4 | -5.0 | 27.9 | 16.4 | 1.1 | 38.4 | 57.3 |
| LP 98-13 | 3.6 | 10.8 | 40.9 | 21.6 | 5.2 | 57.7 | 58.6 |
| Commercial carioca group | | | | | | | |
| Carioca | 15.1 | 7.3 | 61.0 | 7.3 | 3.4 | 66.7 | 57.6 |
| LP 97-4 | 5.4 | 21.0 | 30.7 | 40.3 | 9.8 | 46.3 | 48.9 |
| LP 97-13 | 34.8 | -0.2 | 28.5 | 31.7 | 5.9 | 33.3 | 53.8 |
| LP 97-23 | 6.7 | 5.9 | 30.0 | 36.5 | 5.4 | 40.7 | 49.2 |
| LP 97-28 | 33.9 | 6.6 | 47.7 | 52.8 | 9.9 | 56.4 | 61.3 |

[1/] NN: number of nodes on the main stem; AP: plant height (main stem length in cm); VP: number of pods per plant; SV: number of seeds per pod; PCS: mean weight of 100 seeds (g); PP grain yield per plant (g); PT total grain yield (kg/ha).
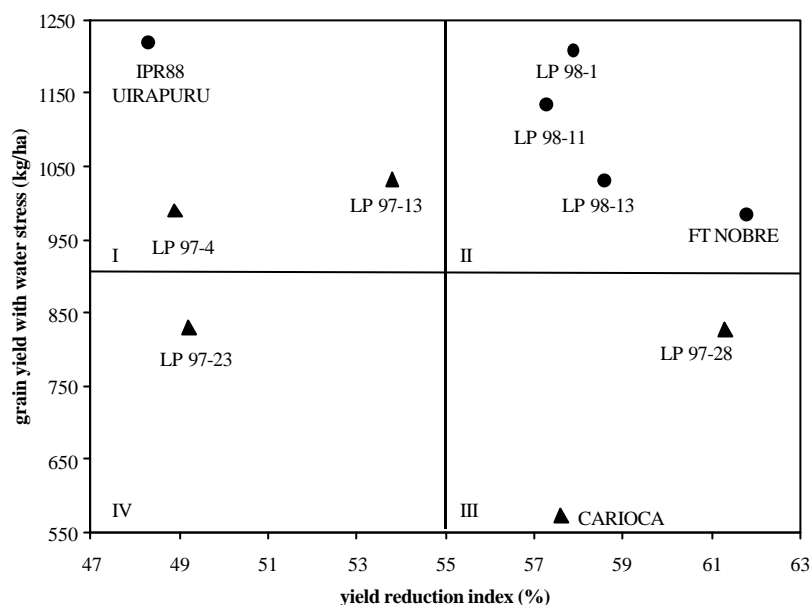
**Figure 2** - Relationship between yield reduction index (%) and grain yield with water stress (kg/ha), of common bean cultivars and lines, of the commercial black group and bean plant cultivars and lines from the commercial carioca group.

The LP98-1 and LP 98-11 lines from the commercial black group and LP 97-4 and LP 97-13 from the commercial carioca group will be selected to be registered in the future for cultivation in the state of Paraná or to be used as parents in common bean breeding programs.

## RESUMO

**Resposta de cultivares e linhagens de feijão comum ao estresse hídrico**

O estudo teve como objetivo avaliar a tolerância ao estresse hídrico de três cultivares e sete linhagens de feijoeiro (*Phaseolus vulgaris* L.) pertencentes aos grupos comercias preto e carioca. Foram estabelecidos em Londrina, na safra das águas/2000, dois ensaios independentes, um para cada grupo. O delineamento experimental utilizado foi o de blocos ao acaso com parcelas subdivididas e três repetições. Os tratamentos com e sem estresse hídrico constituíram as parcelas e os cultivares e linhagens, as subparcelas. Foram avaliados a produtividade e os componentes de produtividade de grãos. Os resultados mostraram variabilidade genética entre os cultivares e linhagens, através das estimativas dos coeficientes de variação genética, ambiental e índice B. O estresse hídrico provocou redução de aproximadamente 50% na produtividade de grãos, sendo que o cultivar IPR88 Uirapuru, do grupo comercial preto, e as linhagens LP 97-13 e LP 97-4, do grupo comercial carioca, destacaram-se como tolerantes à seca e com alto potencial produtivo.

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