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DROUGHT RESISTANCE OF CARIBBEAN AND CENTRAL AMERICAN COMMON BEAN (*Phaseolus vulgaris* L.) LINES

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ABSTRACT. Common bean (*Phaseolus vulgaris* L.) production in many regions occurs under rainfed conditions where water deficit limits yield and causes instability of production. A field study was conducted to evaluate the response of nine Caribbean and Central American common bean lines under rainfed conditions in St. Croix, U.S. Virgin Islands and to assess N fixation under limiting and non-limiting moisture conditions. The lines included nodulating and non-nodulating isolines of BAT 477 and DOR 364. The study used a split plot arrangement in randomized complete block design with moisture as the main plot, genotypes as subplot, and four replications. Higher than normal precipitation impeded the development of moisture deficit in the rainfed treatment, so yield did not differ between rainfed and control treatments. Yield of the nine genotypes ranged from 142 to 1508 kg ha^{-1}. Yield of XAN 176, DOR 364 (nodulating), and 9603-22 exceeded 1300 kg ha^{-1}, despite infestations of common blight (*Xanthomonas campestris* pv. Phaseoli), Cercospora (*Cercospora canescens*), bean leafskeletonizer (near *Autoplasia spp*), and ozone damage. Yield was reduced by 17 and 27% in the non-nodulating isolines of BAT 477 and DOR 364, respectively. The genotypes ICA Palmer and SEA5 had the lowest yield, each producing less than 700 kg ha^{-1}. Days to flower ranged from 34 (9603-22 and ICA Palmer) to 38 days after planting (DAP) and days to maturity ranged from 69 (9603-22) to 75 DAP (BAT 477, BAT 477 (non-nodulating), SEA5, and 8-42-M-2).

INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is the principal food legume of more than 500 million people in Latin America, Asia, and Africa. For more than 100 million of them, it is the leading source of dietary protein (CIAT, 1984). Common bean production in many regions occurs under rainfed conditions where water deficit limits yield and causes instability of production (Ehleringer, 1991; White *et al.*, 1994).

Although agronomic practices are important under water deficit, cultivar improvement is usually seen as the most promising approach to increase yields. Research has indicated that direct selection for seed yield in common bean can be effective, although time-consuming and costly, both for well-watered (Nienhuis and Singh, 1988; Singh *et al.*, 1990) and deficit conditions (White *et al.*, 1994). The objective of this study was to determine the effect of soil water availability on seed yield in nine common bean genotypes grown under rainfed and control conditions and to assess N fixation in each line under rainfed and control conditions.

MATERIALS AND METHODS

An experiment was conducted at the U.S.D.A. Agricultural Research Station, Kingshill, St. Croix, U.S.V.I. (17^0 42' N, 64^0 48' W, and 33.5 masl) in 1999. Mean temperature at the research station was 26.1C with a minimum of 21.9C and a maximum of 30.3C. Seeds were planted on 9 March and harvested on 1 June, 1999. The soil at the St Croix Experimental Station field site was classified as a Fredensborg loamy, fine carbonatic, isohyperthermic, shallow, typic calciustoll with pH ranging from 7.6 to 8.4. A soil sample from each plot was analyzed by the Michigan State University Plant Nutrient and Soil Testing Laboratory for N, P, and K. Soil samples were bulked by replication and analyzed for Zn, Mn, and Cu. As indicated by soil analysis, 22 Kg P/ha, 5.6 kg Zn/ha, and 10 kg Mn/ha were applied. Applications of fungicide, Sevin 80WP (1.5 lb ai/A) and Diazinon AG500 (0.375 lb ai/A), were made at one week intervals starting on March 26. One application of Benlate (500g per 25gal/A) and M-Pede (Potassium salts of fatty acids) (2.5 oz per gallon/A) were made on April 18 for control of Cercospora (*Cercospora canescens)*.

Nine common bean genotypes with Type II growth habit were selected for inclusion in this study: BAT 477 (nodulating and non-nodulating), DOR 364 (nodulating and non-nodulating), XAN 176, ICA Palmer, 8-42-M-2, SEA5, and 9603-22, local check (obtained from Dr. James Beaver in Puerto Rico). BAT 477 and 8-42-M-2 were the drought resistant and drought susceptible check, respectively.

Seeds were planted into four-row plots of 0.5 m row spacing and 2.48 m length. Due to limited seed of ICA Palmer, each row was planted at a density of 25 seeds and thinned to 23 plants. The study utilized a randomized complete block design with four replications, moisture as the main plot, and genotype as subplot. Moisture stress was initiated 22 days after planting (DAP) by cessation of irrigation.

Plots were sampled weekly starting at 23 DAP for stomatal conductance, leaf temperature, and leaf transpiration. Plants were visually scored for disease on a scale of 0 to 9, with 9 being severely damaged and 0 being no visual damage. Days to flower (DF), defined as the number of days when 50% of the plants had one open flower; days to physiological maturity (DPM), defined as the number of days for 75 to 90% of the pods to lose their green pigmentation; and days to seed fill (DSF=DPM-DF) were also recorded. Soil moisture was recorded on 44, 51, and 58 days after planting (DAP) using a Sentry 200-AP moisture probe (Troxler Electronics Laboratories, Inc.). A hard soil pan existed at a depth of approximately 12" at the Agricultural Research Station, so soil moisture was only recorded at a depth of 12 inches. Soil moisture was maintained at 30 cbars in the control treatment throughout the growing season. At harvest, seed yield was determined at 18% moisture. The MSTAT micro-computer statistical package (Michigan State University) for agricultural sciences was used for all data analysis.

RESULTS AND DISCUSSION

Soil pH across plots ranged from 7.6 to 8.0 (Data not shown). Soil NO^{-3} ranged from 39.17 to 129.06 lbs/acre-foot with a mean of 85.46 and soil NH_4 ranged from 6.88 to 19.88 lbs/acre-foot with a mean of 140.24 (Table 1). No N fertilizer was applied, since N fixation was being assessed. Total soil N was higher than desirable in an N fixation study, definitely aiding the yield of the non-nodulating lines. As the growing season progressed, there was a noticeable lighter green color on the non-nodulating isolines and the non-nodulating isolines of BAT 477 and DOR 364 had a 27 and 17% yield reduction, respectively, in comparison to their nodulating isolines. The N fixation data is currently under analysis.

Table 1. Replication effect on soil nutrient level of nine bean (*Phaseolus vulgaris* L.) genotypes grown at the Agricultural Research Station, U.S.V.I. 1999.

Rep	Soil pH	‡NO^{-3}	§NH^{+4}	K^{+1}	Ca^{+2}	Mg^{+2}	Olsen P
					lbs $acre^{-1}$		
I	7.90 ab*	82.58 ns	8.78 c+	1477 b+	17800 ns	757 b*	33 b*
II	7.94 a	82.84	9.42 bc	1415 b	17183	723 b	29 b
III	7.88 bc	87.50	12.03 a	1505 b	17579	1059 a	33 b
IV	7.84 c	88.00	10.76ab	1650 a	17688	893 ab	42 a
Grand mean	7.89	85.48	10.25	1512	17563	858	34
C.V.	1	20	20	11	6	14	28

+, * Different letters indicate significant difference among means within a column at < or = to 0.10 and 0.05, respectively, according to DMRT, ns=Indicates no significant difference among means within a column, ‡= lbs per acre foot, §=lbs per acre furrow slice.

There were no significant differences among genotypes for soil K^+, Ca^{+2}, Mg^{+2}, and Olsen P (Data not shown), however there were significant differences among replications for soil pH (< or = to 0.05), K^+ (< or = to 0.10), Mg^{+2} (< or = to 0.05), and Olsen P (< or = to 0.05) (Table 1). Soil P levels were low and soil Mg, Ca, and K levels were high (Wolf, 1996).

Precipitation was higher than normal, so moisture stress did not occur. This was reflected by the fact that soil moisture did not differ between rainfed and control plots except for one of the three sampling dates. Thus, there was no yield difference between rainfed and control treatments. Consequently, yield is reported as the mean of rainfed and control plots combined. Yield of the nine genotypes ranged from 142 to 1508 kg ha^{-1} (Table 2). DOR 364 (nodulated), XAN 176, and the local check 9603-22 had a significantly higher (< or = 0.01) yield than the genotypes ICA Palmer, BAT 477 (non-nodulating), SEA5, and 8-42-M-2 but not significantly higher than BAT 477 (nodulated) and DOR 364 (non-nodulating). BAT 477 was used as a drought resistant check since numerous studies have documented its resistance (CIAT, 1984; Gregory, 1989).

Plants were severely infected with common blight, Cercospora, and bean leafskeletonizer (*Autoplusia* spp), and also had ozone damage. ICA Palmer had a significantly higher (< or = to 0.01) rating for common blight than all other genotypes (Table 3). Common blight affects the foliage and pods of beans and is considered to be a major problem in most bean production areas of the world. During extended periods of warm, humid weather, the disease can be highly destructive, causing losses in both yield and seed quality. Common blight typically develops from (1) planting contaminated seeds, (2) planting seeds in a contaminated field, and (3) when the climate is consistently hot and wet or humid (Hall, 1994). Clean seed was planted, so common blight must have been preexisting in the soil and the weather conditions were hot and wet throughout the growing season. In fact, the unusually high amount of rainfall prohibited the desired water stress, the primary reason for planting in January.

Palmar produced yields exceeding 2000 kg^{-1} ha at the Agricultural Research Experiment Station in Isabela, Puerto Rico, demonstrating its high yield potential (Personal Communication). The severe common blight infestation, the mild infestation of Cercospora, ozone damage, and feeding damage from the bean leafskeletonizer were significant contributors to the low yield of ICA Palmar obtained at St. Croix. Inexplicably, ICA Palmar did not reach maturity (Table 2), although there is no difference in photoperiod between Isabela, Puerto Rico, and St. Croix.

Table 2. Combined yield (kg ha^{-1}), yield under stress (kg ha^{-1}), days to flower, days to physiological maturity, leaf dry weight, and root dry weight of nine bean (*Phaseolus vulgaris* L.) genotypes grown at the Agricultural Research Station, U.S.V.I. 1999.

Genotypes	†Combined yield	‡DF	§DPM	Leaf dry wt (g)	Root dry wt (g)
BAT 477	1035.54 abc**	38	75	14.84 a**	1.28 c*
9603-22	1476.23 a	34	69	10.12 b	1.35 bc
DOR 364 (nn)	1255.62 ab	38	73	11.13 ab	1.25 c
ICA Palmer	141.70 d	34	—	14.13 ab	1.30 c
XAN 176	1396.86 a	38	73	10.02 b	1.40 abc
BAT 477 (nn)	755.59 bc	38	75	14.81 a	1.34 bc
SEA5	633.39 cd	38	75	14.53 ab	1.20 c
8-42-M-2	738.70 bc	38	75	11.54 ab	1.74 a
DOR 364	1508.35 a	38	73	11.97 ab	1.69 ab
Grand mean	993.55	—	—	12.57	1.394
C.V.	37	—	—	24	24

*,** Different letters indicates significant difference among means within a column at < or = to 0.05 and 0.01, respectively, according to DMRT. †=Indicates combined stress and non-stress yield, ‡=Indicates days to flower, §= Indicates days to physiological maturity.

Table 3. Common blight, common blight, and ozone rating of nine bean (*Phaseolus vulgaris* L.) genotypes grown at the Agricultural Research Station, U.S.V.I. 1999.

Genotypes	Common blight	Cercospora	Ozone
BAT 477	4.75 b**	6.20 b**	3.63 ab*
9603-22	2.36 c	2.75 cde	4.88 a
DOR 364 (nn)	2.19 c	2.31 de	3.38 b
ICA Palmer	8.25 a	3.50 cd	2.88 b
XAN 176	2.50 c	2.31 de	2.44 b
BAT 477 (nn)	3.63 bc	4.44 c	3.38 b
SEA5	4.38 b	8.75 a	3.88 ab
8-42-M-2	3.75 bc	3.13 cde	3.50 b
DOR 364	1.94 c	1.38 e	2.50 b
Grand Mean	3.75	3.68	3.38
C.V.	33	33	37

*,** Different letters indicates significant difference among means within a column at < or = to 0.05 and 0.01, respectively, according to DMRT.

Bean leafskeletonizer (near *Autoplasia spp.*) infected the plants and added to defoliation problems, but these pests were quickly brought under control. Cercospora occurs in Latin America and the southern United States. It can affect all aerial parts of common bean and result in defoliation. Serious yield losses caused by the disease have not been reported.

The Cercospora rating for SEA5 was significantly higher (< or = to 0.01) than that of all other genotypes (Table 3), and ozone damage was significantly greater (< or = to 0.05) on 9603-22 than on all other genotypes except BAT 477 and SEA5 (Table 3). Previous work with SEA5 and BAT 477 in Mexico (Personal Communication with Dr. Jorge Acosta) produced yields that were appreciably higher than the ones obtained in this study. Undoubtedly, common blight, Cercospora, ozone damage, and the bean leafskeletonizer negatively affected yield. Nevertheless, the average yield obtained in this study, is greater than the average yield obtained in many areas of the Caribbean and demonstrate the adaptability of common bean to St. Croix and the ability to produce fairly good yields despite insect and disease problems. This is important because Crucians consume large quantities of common bean, but common bean is not produced commercially on the island and little or none even in home gardens.

ICA Palmer and the Puerto Rican check 9603-22 were the first genotypes to flower (34 DAP) compared to the other genotypes which took 38 DAP, however, ICA Palmer never reached physiological maturity. The other genotypes matured over a range of 69 to 75 DAP (Table 2). ICA Palmer also had a significantly higher (< to = 0.10) leaf temperature (Data not shown) than the other genotypes, suggesting greater stomatal closure than the other genotypes. Yet, transpiration did not differ among the genotypes.

Significant genotypic differences were observed for leaf and root dry weight (< to = to 0.01 and 0.05, respectively), but not for stem dry weight. The genotypes BAT 477 and BAT 477 (nn) had a significantly higher leaf dry weight than 9603-22 and XAN 176 but not significantly higher than the other genotypes (Table 2). The genotype 8-42-M-2 had a significantly higher root dry weight than all genotypes, except XAN 176 and DOR 364 (Table 2).

CONCLUSIONS

Days to flower ranged from 34 to 38 DAP and days to maturity ranged from 69 to 75 DAP. Yield for the nine genotypes used in this trial ranged from 142 to 1508 kg ha^{-1}. Yield was severely reduced by a combination of common blight, Cercospora, ozone damage, and bean leafskeletonizer. The unusually high amount of rainfall contributed to the lack of water stress throughout the growing season, and high humidity and rainy days were ideal environments for Cercospora and common blight. The genotypes ICA Palmer and SEA5 had the greatest yield reduction due to these diseases, each producing less than 700 kg ha^{-1}.

However, XAN 176, DOR 364, and the line 9603-22 produced yields exceeding 1300 kg ha^{-1}. Relatively high yields are possible in St. Croix despite high soil pH, shallow soil, and pest problems.

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