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Short Communication

Evaluation of *Phaseolus acutifolius* A. Gray plant introductions under high temperatures in a controlled environment

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Abstract

Heat susceptibility is a cause of yield loss in common bean (*Phaseolus vulgaris* L.) in temperate and tropical lowland growing regions. Interspecific hybridization with related species that include tepary bean (*Phaseolus acutifolius* A. Gray) can potentially be used to transfer heat tolerance traits to common bean. This study evaluated 25 tepary bean plant introductions (PIs) following exposure to high-temperature (35 °C day/32 °C night) and control temperature (27 °C day/24 °C night) during reproductive development. These 25 PIs were selected for high yield potential in a 14 h photoperiod greenhouse environment. High temperature when compared to non-stress treatment resulted in a mean reduction in seed yield of 88.8% among tepary beans and caused 100% yield loss in common beans. Twelve *P. acutifolius* PIs exhibited negligible yield under heat-stress when compared to control treatment. Although yields of these accessions were low under very high-temperature conditions, PI 200902, PI 312637, PI 440785, PI 440788, and PI 440789 exhibited the highest yield component stability under the high temperature treatment.

Introduction

Tepary bean (*Phaseolus acutifolius* A. Gray) is a crop adapted to hot arid climates and is grown in the American Southwest and parts of Mexico during summer when temperatures are too high for pod formation in common bean (Nabhan and Felger 1978; Thomas et al. 1983). Tepary beans have also produced higher yields than common bean in other heat stress environments (Scully and Waines 1988; Miklas et al. 1994).

By controlling vapor pressure deficit under heat-stress conditions (thereby eliminating heat-induced water stress), Lin and Markhart (1996) have shown that tepary bean is more heat-tolerant than common bean at the tissue level, and produces more leaves to compensate for reduced leaf size due to heat. Mitochondria isolated from tepary bean are more heat tolerant than those from common bean (Lin and Markhart 1990), and tepary beans germinate at higher temperatures than common bean (Scully and Waines 1988).

High temperatures (> 30 °C day and/or > 20 °C night) in tropical lowlands and production areas in temperate zones reduce yield and quality in common bean (*P. vulgaris* L.) (Singh 2001). As a member of the tertiary gene pool of common bean, tepary bean is a potential donor of heat-tolerance traits to common bean through interspecific hybridization, although the cross is difficult and requires embryo rescue. The purpose of this study was to identify heat-tolerant tepary beans with good agronomic traits for hybridization with common bean.

Materials and methods

The USDA *P. acutifolius* collection (W-6 Regional Plant Introduction Station, Pullman, WA) consists of 240 accessions, 129 of which were available for testing. Of the 129 PIs, only 25 (Table 1) exhibited high pod set in a 30 °C day/25 °C night greenhouse with 14 h photoperiod in a previous study. These 25 PIs were evaluated for ability to set pods and seeds in stress and non-stress environments. Control plants included heat-tolerant common beans 'Carson', 'Cornell 503' and 'Venture' and the heat-sensitive common bean, 'Majestic' (Rainey and Griffiths in press). Also included were

Table 1. Mean pod number and means seeds per pod for 25 USDA *P. acutifolius* PIs grown under controlled-environment temperature conditions.

Accession	Origin	Pod Number			Seed Number		
		Control treatment 27/24 °C (day/night)	High temperature treatment 35/32 °C (day/night)	Yield reduction [%]	Control treatment 27/24 °C (day/night)	High temperature treatment 35/32 °C (day/night)	Yield reduction [%]
PI 197041	El Salvador	42.83 a–d*	1.67 d	96.1	206.67 a–d	7 b–d	96.6
PI 200749	El Salvador	43.67 a–d	0.67 d	98.5	216.50 a–c	3 cd	98.6
PI 200902	El Salvador	32.67 c–f	8.0 a–d	75.6	162.33 a–f	30.0 a–c	81.5
PI 201268	Mexico	37.0 b–e	0.17 d	99.5	154.0 a–f	0.33 cd	99.8
PI 209480	Nicaragua	39.67 b–d	0.67 d	98.3	179.33 a–e	3.33 d	98.1
PI 239056	Morocco	41.20 b–d	6.17 b–d	85.0	192.4 a–d	20.5 b–d	89.3
PI 310800	Nicaragua	33.0 c–f	0 d	100	157.17 a–f	0 d	100
PI 310801	Nicaragua	27.5 d–f	3.17 d	88.5	153.0 a–f	15 b–d	90.2
PI 310802	Nicaragua	34.67 c–f	3.83 d	89.0	113.50 c–h	17.83 b–d	84.3
PI 310803	Nicaragua	40.5 b–d	0.17 d	99.6	197.67 a–d	0.67 b–d	99.7
PI 312122	El Salvador	39.67 b–d	1.5 d	96.2	174.50 a–e	7.33 b–d	95.8
PI 312198	Mexico	63.17 a	0.17 d	99.7	178.0 a–e	0.67 d	99.6
PI 319443	Mexico	47.50 a–d	0 d	100	212.5 a–c	0 d	100
PI 319551	Mexico	15.33 fg	1.67 d	89.1	42.0 gh	6.83 b–d	83.7
PI 321637[z]	Arizona	41.83 b–d	7.33 a–d	82.5	197.33 a–d	42.0 a–c	78.7
PI 321638[z]	Arizona	48.6 a–d	4.67 cd	90.4	236.8 ab	22.0 b–d	90.7
PI 331181	Argentina	46.17 a–d	0 d	100	134.17 b–g	0 d	100
PI 406633	Arizona	46.5 a–d	7.83 a–d	83.2	209.17 a–c	21.0 b–d	90.0
PI 430208	Peru	2.5 fg	7.50 a–d	–200	10.50 h	32.67 a–c	–211
PI 440785	Mexico	49.17 a–d	17.0 a	65.4	252.17 a	42.0 a–c	83.3
PI 440786	Mexico	51.33 a–c	5.17 cd	89.9	232.33 ab	19.17 b–d	91.7
PI 440787	Mexico	43.1677 a–d	0 d	100	228.83 ab	0 d	100
PI 440788[z]	Mexico	53.17 a–c	14.17 a–c	73.4	199.33 a–d	46.33 ab	76.8
PI 440789	Mexico	44.33 a–d	15.68 ab	64.7	141.50 a–g	64.33 a	54.5
PI 440790	Mexico	57.33 ab	6.83 b–d	88.1	228.50 ab	26.67 a–c	88.3
MEAN		40.90	4.56	88.8	176.41	17.15	90.3
Common Bean							
Carson		16.0 fg	0 d	100	68.0 f–h	0 d	100
Cornell 503		16.17 fg	0 d	100	77.0 e–h	0 d	100
Majestic		29.0 ef	0 d	100	95.17 d–h	0 d	100
Venture		18.83 e–g	0 d	100	77.17 e–h	0 d	100
MEAN		20.0	0	100	79.34	0	100

*Means within a yield component and treatment not followed by the same letters are significantly different at $P \leq 0.05$ according to Duncan's multiple range test.

[z]Cultivated lines identified by Miklas et al. (1994) as having large seeds, high vigor, yield potential, disease resistance and heat tolerance in the field, and independently selected by the authors for agronomic characteristics.

'ICA Pijao', a common bean that facilitates hybridization between tepary and common beans (Mejía-Jiménez et al. 1994), and a *P. acutifolius* × *P. vulgaris* BC_1F_1 interspecific hybrid line [('ICA Pijao' × PI 319443) × 'ICA Pijao'] developed for drought tolerance (Giles Waines, Univ. CA, Riverside, CA).

Seeds were sown in 20 cm diameter pots filled with 'Cornell mix' (Boodley and Sheldrake 1972) on June 15th 2003 in two 90 m^2 plastic houses and thinned to one plant per pot. In each house there were two replications of three plants for each entry (accession, line or cultivar) and entries were randomized within each replication. All plants were irrigated and fertilized as needed and supplemental lighting was provided by 1000 W metal halide bulbs (300 $\mu mol\ m^{-2}\ s^{-1}$). During seedling growth and germination, temperatures were 27 °C day/24 °C night with a 14 h photoperiod. Seven days prior to anthesis temperatures were raised to 35 °C day/32 °C night in the high temperature house, this heat treatment continued through reproductive development and the onset of plant senescence. The second house remained at 27 °C day/24 °C night as a control treatment. Pod and seed number were recorded for each entry.

Results and discussion

All common beans tested, including heat-tolerant lines, exhibited zero seed set in the high-temperature greenhouse. Among tepary beans, mean pod number was 4.56 and mean seed number was 17.15 following exposure to high-temperature, and 40.90 and 176.41, respectively, in the control environment (Table 1). Heat stress was severe, resulting in yield component reductions > 90% among 12 of the 25 tepary PIs evaluated. Also, neither the ('ICA Pijao' × PI 319443) × 'ICA Pijao' backcross plants nor the parents were heat-tolerant.

The tepary beans with the highest relative yields under heat-stress (PI 200902, PI 312637, PI 440785, PI 440788, and PI 440789) were from diverse geographic origins. These accessions are labeled as heat-tolerant relative to the other tepary beans and common beans in the study, but nevertheless displayed significant reductions in pod and seed set under high temperature as compared to control temperature. Therefore, based on relative yield stability under conditions of 35 °C day and 32 °C night, PI 200902, PI 312637, PI 440785, PI 440788, and PI 440789 could be used for interspecific hybridization with common bean to transfer gene(s) controlling heat tolerance. High temperatures increased yield in PI 430208, suggesting this accession may be adapted to high temperature environments. In addition, two of the heat-tolerant tepary accessions identified in this study (PI 321637 and PI 440788) were found by Miklas et al. (1994) to have large seeds, high vigor and yield potential, resistance to common bacterial blight (*Xanthomonas campestris* pv. *phaseoli*), and tolerance to high-temperature field conditions. Additional beneficial traits observed in these accessions include resistance to powdery mildew (*Erysiphe polygoni*) in PI 321637, and resistance to bean rust (*Uromyces appendiculatus* (Pers.)) in PI 440788 (Miklas et al. 1994).

In conclusion, tepary bean accessions able to set substantial numbers of pods and seeds under very high temperature conditions were identified. Heat-tolerant common bean lines displayed no yield under this temperature regime. These accessions also possess agronomic characteristics and are potential donors of genes to improve common bean through interspecific hybridization. However, hybridization between *P. vulgaris* and *P. acutifolius*, is difficult and it is not clear whether levels of heat-tolerance displayed by these accessions would warrant such efforts.

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