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Pinto bean response to seeding rate and herbicides

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Abstract

Field experiments were conducted in 2016 and 2017 to evaluate the effects of seeding rate and herbicide programs on weed control and pinto bean yield under irrigation. The experiments comprised a 5 × 5 factorial randomized complete block design with five replications. The weed control treatments comprised a nontreated control, hand-weeded control, EPTC + ethalfluralin PRE, EPTC + ethalfluralin PRE followed by (fb) dimethenamid-P POST at V1, and EPTC + ethalfluralin PRE fb bentazon/imazamox POST. There were five seeding rates ranging from 247,000 to 494,000 seeds ha^{-1} planted in 19-cm rows. Weed biomass was reduced by 6 kg ha^{-1} with every additional 1,000 seeds ha^{-1}. EPTC plus ethalfluralin fb either dimethenamid-P or bentazon plus imazamox reduced weed biomass by at least 29% compared to the nontreated control. There was a significant effect of weed control treatment on pinto bean yield ($P = 0.0004$). However, there was no significant seeding rate ($P = 0.42$) or seeding rate–by–weed control interaction effect on pinto bean yield ($P = 0.38$). Pinto bean yield ranged from 3,080 kg ha^{-1} in the nontreated control to 4,740 kg ha^{-1} hand-weeded treatment. Increased seeding rate in narrow rows is a cultural practice that can improve weed control in pinto bean but may not necessarily increase yield.

Introduction

Dry bean is an important crop in the western United States. This region produces about 124,000 ha of dry bean annually, with a market value of US $210 million (Soltani et al. 2018a). Weed control is one of the major concerns in dry bean production (Taziar et al. 2017), because dry bean is a short-stature crop and therefore a relatively poor competitor for sunlight.

In the United States and Canada, potential annual dry bean yield loss from uncontrolled weeds is 71%, which translates to more than US $722 million in value (Soltani et al. 2018a). In addition to yield loss, weeds present at harvest can reduce dry bean quality, thereby reducing the market value of the crop (Hekmat et al. 2008; Pynenburg et al. 2011; Taziar et al. 2017). Seed rain from uncontrolled weeds can also become a major weed problem in the next crop (Brouwer et al. 2015). Weed control is therefore a critical management practice in dry bean production (Vangessel et al. 1998; Wilson 2005).

Chemical weed control in the form of herbicide application remains one of the most important weed management tools in dry beans. However, the limited number of effective herbicides for broadleaved weed control in dry beans compared to major crops such as corn (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.] (Soltani et al. 2018b) necessitates identifying other effective herbicides (Adjesiwor et al. 2020; Soltani et al. 2005) or integrating multiple methods for effective weed control in dry bean (Norris et al. 2002; Waters and Morishita 2001). Nonchemical weed control practices include, but are not limited to, reducing row width and increasing plant population (Waters and Morishita 2001). The costs and benefits of planting in narrow rows have been summarized by Hesterman et al. (1987). Advantages include earlier canopy closure, increased light interception, reduced within-row weed competition, and increased yields. The disadvantages are increased planting cost, increased risk of lodging, and increased risk of disease (Hesterman et al. 1987). The effect of narrow rows and increased seeding rates on weed control has been investigated to a lesser extent. Research in Canada has shown that narrow row spacing and increased seeding rate in black and white beans resulted in earlier canopy closure and better suppression of annual weeds (Blackshaw et al. 1999; Malik et al. 1993). Also, narrow row spacing and high seeding density increased seed yield of black and small red dry bean (Blackshaw et al. 1999, 2000).

However, it is unclear if these weed suppression and yield advantages of narrow row spacing and increased seeding rate in black and white beans are similar in other dry bean market classes. Research has shown that dry bean market classes and cultivars often respond differently to weed management practices (Malik et al. 1993; Soltani et al. 2005). For example, in white bean, the cultivars 'OAC Gryphon' and 'OAC Laser' reduced weed biomass by 10% to 35% more than 'OAC Spring' (Malik et al. 1993). Thus, it is important to assess how other dry bean market classes such as pinto bean would respond to these weed management practices. This study was conducted to determine if there are advantages of growing pinto beans at an increased seeding rate and in narrow rows. Specifically, the study evaluated the effect of seeding rate and herbicide programs on weed control and pinto bean yield under irrigation.

Materials and Methods

Field experiments were conducted in 2016 and 2017 at the University of Idaho Kimberly Research and Extension Center in Kimberly, ID (42.55°N, 114.35°W). The soil was a Portneuf silt loam (coarse-silty, mixed, superactive, mesic Durinodic Xeric Haplocalcids) with 23% sand, 58% silt, and 19% clay with a pH of 7.8, organic matter content of 2%, and a cation exchange capacity of 19.0 mEq per 100 g soil. Prior to study establishment, common lambsquarters (*Chenopodium album* L.), redroot pigweed (*Amaranthus retroflexus* L.), hairy nightshade (*Solanum physalifolium* Rusby), and green foxtail [*Setaria viridis* (L.) Beauv.], seeds were broadcast and incorporated with a roller harrow (Farmhand CM41 Cultimulcher; AGCO, Duluth, GA) at a rate of 270 seeds m^{-2} for each species on May 18, 2016 and May 30, 2017. This was done to ensure weed uniformity in all plots. The experiment had 25 treatments in a 5 × 5 factorial randomized complete block design with five replications. Treatments comprised five weed control treatments (Table 1) and five seeding rates (247,000, 309,000, 371,000, 432,000, and 494,000 plants ha^{-1} in rows spaced 19 cm apart). Plots were 2.23 m wide and 7.62 m long (17 m^2 area). Pinto bean was seeded with a Great Plains 3P806NT drill (Great Plains Ag U.S.A. Salina, KS). Planting dates were June 2, 2016 and June 5, 2017. The pinto bean variety was 'LaPaz' (ADM, Chicago, IL), which is an upright indeterminate Type II dry bean. Beans were irrigated with an overhead solid-set sprinkler as needed based on evapotranspiration. In both years, hand-weeding treatment started 2 wk after emergence (WAE) and continued every 1 to 2 wk until canopy closure.

Bean density counts were taken on June 20, 2016 and June 20, 2017, 1 and 2 WAE, respectively. Weed control was assessed visually after the POST herbicide treatments, which correspond to 7 and 5 WAE in 2016 and 2017, respectively. Weed control was rated on a scale of 0 to 100%, with 0% representing no weed control and 100% complete weed control. The weeds evaluated were common lambsquarters, redroot pigweed, hairy nightshade, and green foxtail. Weed biomass samples were taken 17 and 15 WAE in 2016 and 2017, respectively. Weed biomass was determined by harvesting all of the weeds in a 1-m^2 area and drying at 60 C for 48 h.

At maturity, the two center rows of each plot were harvested using a Pickett bean cutter (Pickett Equipment, Burley, ID) on October 5, 2016 and October 24, 2017. The plants were air-dried and threshed with a Wintersteiger Delta plot combine (Wintersteiger Inc., Salt Lake City, UT) to determine seed yield.

All data analyses were performed in R statistical language version 4.0.2 (R Core Team, 2020) using the lmerTest and emmeans packages (Kuznetsova et al. 2017; Lenth 2020). Visible weed control, weed biomass, and pinto bean yield were analyzed using a mixed-effects model, where weed control treatments and seeding density were considered fixed effects and block and year were considered random effects. Estimated marginal means were calculated from the model, and post-hoc Tukey-adjusted pairwise treatment comparisons were performed at $\alpha = 0.05$ using the emmeans and multcomp package (Hothorn et al. 2008; Lenth 2020). A linear regression analysis was used to assess the relationship between the quantitative fixed-effect variable (seeding density) and weed biomass and pinto bean yield. The relationship between pinto bean density at 2 wk and yield was assessed using Pearson correlation. All figures were plotted using the ggplot function of the tidyverse package (Wickham et al. 2019).

Table 1. Weed control treatments, herbicide rates and application timings in 2016 and 2017, Kimberly, ID.

Weed control treatment[a]	Rate	Timing
	kg ai ha^{-1}	
Nontreated control	–	–
Hand-weeded control	–	–
EPTC[b] + ethalfluralin[b]	2.92 + 1.25	PRE[e]
EPTC + ethalfluralin	2.92 + 1.25	PRE
fb dimethenamid-P[c]	0.83	POST[f]
EPTC + ethalfluralin	2.92 + 1.25	PRE
fb bentazon & imazamox[c,d]	0.77	POST

[a]Abbreviations: fb, followed by.
[b]Gowan Company, Yuma, AZ.
[c]BASF, Research Triangle Park, NC.
[d]Treatment contained methylated seed oil (Superspread MSO; Wilbur-Ellis Co., P.O. Box 16458, Fresno, CA) at 1% v/v.
[e]Water incorporated using sprinkler irrigation.
[f]Applied at first trifoliate growth stage.

Table 2. Visual weed control in response weed control treatments in 2016 and 2017, Kimberly, ID.

Weed control treatment	Common lambsquarters[a]	Redroot pigweed	Hairy nightshade	Green foxtail
	%			
Hand-weeded control	95 a	93 a	97 a	91 a
EPTC + ethalfluralin	40 b	59 a	43 b	74 a
EPTC + ethalfluralin fb dimethenamid-P	41 b	70 a	50 b	94 a
EPTC + ethalfluralin fb bentazon + imazamox	48 b	91 a	87 a	96 a
P value	0.001	0.139	0.05	0.064

[a]Within column, means followed by the same letter are not different at the 0.05 probability level according to Tukey's HSD. Weed control evaluations were completed 7 and 5 wk after emergence in 2016 and 2017, respectively.

Results and Discussion

Row spacing and seeding rate did not affect weed control ($P > 0.05$). Herbicide treatments provided at least 74% control of green foxtail and 40% to 95% control of broadleaved weeds in this study (Table 2). EPTC plus ethalfluralin followed by bentazon plus imazamox improved hairy nightshade control compared to EPTC plus ethalfluralin or EPTC plus ethalfluralin followed by dimethenamid-P (Table 2).

Total weed biomass was not affected by row spacing ($P = 0.99$) (data not presented). However, weed biomass was influenced by weed control treatments ($P = 0.021$) and seeding rate ($P = 0.0012$) (Figure 1). EPTC plus ethalfluralin followed by either dimethenamid-P or bentazon plus imazamox reduced weed biomass by at least 29% compared to the nontreated control (Figure 1). There was a negative linear relationship between seeding rate and weed biomass; with every additional 1,000 seeds ha^{-1},

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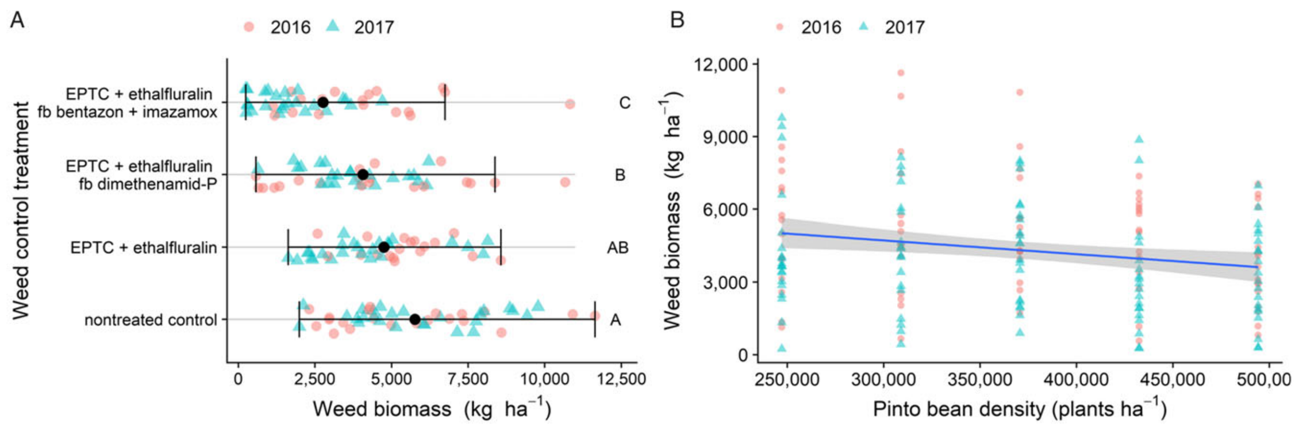

Figure 1. Weed biomass as influenced by weed control treatments (A; P = 0.022) and pinto bean seeding density (B; P = 0.002) in 19-cm-wide rows in 2016 and 2017, Kimberly ID. Each data point represents pinto bean yield in one plot. In part A, solid black points are the estimated marginal means, means followed by the same letter are not different at the 0.05 probability level according to Tukey's HSD, and horizontal bars indicate 95% confidence interval. Linear regression (part B): $y = 6428 - 0.006x$ (P = 0.002; $r^2 = 0.04$). Weed control treatments are described in Table 1.

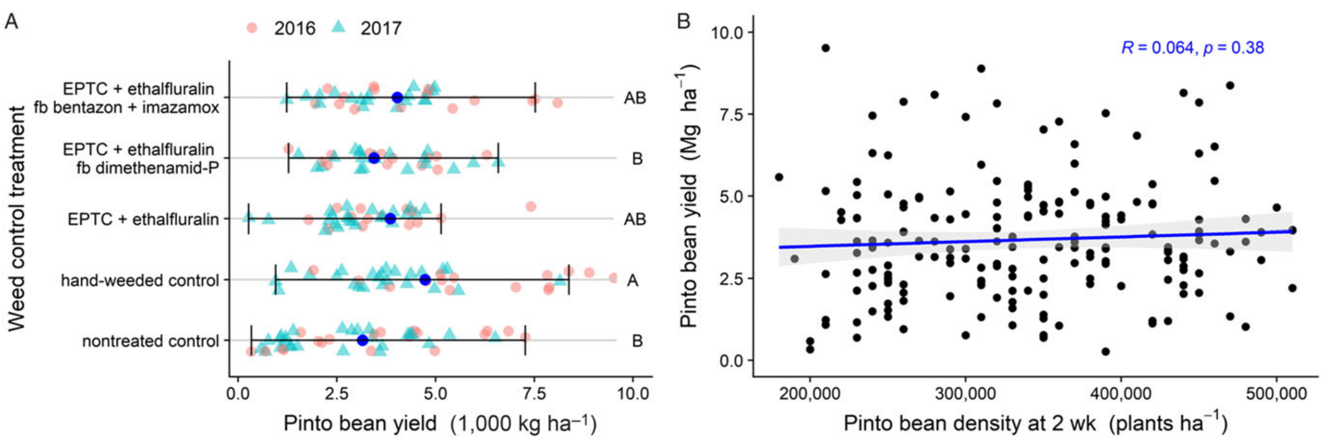

Figure 2. Pinto bean seed yield as influenced by weed control treatments (A; P = 0.0004) and pinto bean density [B; Pearson correlation coefficient (R) = 0.064, P = 0.38] in 19-cm-wide rows in 2016 and 2017, Kimberly ID. Each data point represents pinto bean yield in one plot. In part A, solid blue points are the estimated marginal means, means followed by the same letter are not different at the 0.05 probability level according to Tukey's HSD, and horizontal bars indicate 95% confidence interval. Weed control treatments are described in Table 1.

weed biomass decreased by 6 kg ha^{-1} (Figure 1). This agrees with findings from previous studies that higher seeding rates of dry bean results in better weed suppression through earlier canopy closure and limited light penetration through the canopy (Blackshaw et al. 1999; Malik et al. 1993).

There were no statistical differences in pinto bean density among weed control treatments (P = 0.487), but pinto bean stand density 2 wk after planting was correlated with seeding rate (Pearson's r = 0.91, P < 0.001) (data not presented). This result was expected, as all the herbicides used in this study are registered and safe to use in dry bean (Hekmat et al. 2008; Wilson and Sbatella 2014).

There was a significant effect of weed control treatment on pinto bean yield (P = 0.0004; Figure 2A). However, there was no significant seeding rate (P = 0.42) or seeding rate–by–weed control interaction effect on pinto bean yield (P = 0.38). Pinto bean density measured 2 WAE was not correlated with yield (Pearson's r = 0.06, P = 0.38; Figure 2B), confirming that seeding rate had little to no effect on seed yield. The lack of seeding rate effect on yield suggests that in narrow-spaced pinto bean, a lower seeding rate of 247,000 seeds ha^{-1} could be used to obtain yields similar to that from 494,000 seeds ha^{-1}, potentially saving on seed cost. Among the herbicide treatments, only EPTC plus ethalfluralin reduced pinto bean yield compared with the hand-weeded control (Figure 2A). As there was no stand reduction or observed plant injury due to herbicides, the lower yield in EPTC plus ethalfluralin was probably due to weed interference (Figure 1). Based on these results, pinto beans seeded at higher seeding rates in narrow rows may improve weed suppression but may not necessarily result in higher seed yield.

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