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Wild Buckwheat (*Polygonum convolvulus*) Interference in Sugarbeet

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Field studies were conducted in Powell, WY in 2006 and 2007 to determine the influence of season-long interference of various wild buckwheat densities and duration of interference on sugarbeet. Percent sucrose content was not affected by wild buckwheat interference. Root and sucrose yield loss per hectare increased as wild buckwheat density increased. The estimated percent yield loss as wild buckwheat density approaches infinity was 64 and 61% for root and sucrose yield loss, respectively. The estimated percent yield loss per unit weed density at low weed densities was 6% for both root and sucrose yield loss. Greater durations of wild buckwheat interference had a negative effect on sugarbeet root yield. The critical timing of weed removal (CTWR) to avoid 5 and 10% root yield loss was 32 and 48 d after sugarbeet emergence (DAE), respectively. These results show that wild buckwheat is competitive with sugarbeet and should be managed appropriately to forestall any negative effects on sugarbeet root and sucrose yield.

Nomenclature: Wild buckwheat, *Polygonum convolvulus* L. POLCO; sugarbeet, *Beta vulgaris* L.
Key words: Competition, critical period of weed control, length of competition, rectangular hyperbolic model, timing of removal, weed density.

Estudios de campo realizados en Powell, WY en los años 2006 y 2007 fueron dirigidos para determinar la influenza de larga estación de interferencia de varias densidades de polygonum convolvulus y la duración de interferencia en la remolacha azucarera. El contenido de sacarosa no fue afectado por la interferencia de polygonum convolvulus. La raíz y la pérdida de producción de sacarosa por hectárea se incrementaron tanto como la densidad de polygonum convolvulus se incrementó. El porcentaje estimado de pérdida en la producción mientras la densidad de la polygonum convolvulus se acercó al infinito, fue de un 64 y un 61%, para la raíz y la pérdida de la producción de sacarosa respectivamente. El porcentaje estimado de pérdida en la producción por unidad de densidad de baja maleza fue del 6% para ambos, raíz y la pérdida de producción de sacarosa. Un mayor intervalo de interferencia de la polygonum convolvulus tuvo un efecto negativo en la producción de la remolacha azucarera. El tiempo crítico de remoción de maleza (CTWR) para evitar el 5 y el 10% de pérdida en la producción de la remolacha azucarera fue de 32 y 48 días después de la emergencia de ésta. Estos resultados muestran que la polygonum convolvulus es competitiva con la remolacha azucarera y debe ser manejado apropiadamente para evitar cualquier efecto negativo en la raíz y en la producción de sacarosa.

Wild buckwheat is a significant annual weed in cultivated fields in the Great Plains of North America (Blackshaw and Lindwall 1995; Fabricius and Nalewaja 1968; Gruenhagen and Nalewaja 1969; Stevenson and Wright 1996). The persistence of wild buckwheat has been attributed partly to dormancy of newly ripened achenes (Hume et al. 1983), and its ability to produce up to 30,000 seeds per plant (Forsberg and Best 1964) and recruit seedlings from depths of up to 9.5 cm (du Croix Sissons et al. 2000). These characteristics allow for germination of wild buckwheat to be spread over subsequent years in many crops.

Wild buckwheat rapidly is becoming an important weed in sugarbeet production in the Big Horn Basin of Wyoming. Sugarbeet is most sensitive to weed competition from the early-emerging weeds because of the crop's slow growth and development early in the season (Milford 1973; Schweizer and May 1993; Scott and Wilcockson 1976). Weed competition delays sugarbeet leaf emergence, consequently resulting in storage of lower amounts of sucrose in the root (Paolini et al. 1999). Sugarbeet yield losses due to weed interference from kochia [*Kochia scoparia* (L.) Schrad.], common lambsquarters (*Chenopodium album* L.), redroot pigweed (*Amaranthus retroflexus* L.), Powell amaranth (*Amaranthus powellii* S. Watson), velvetleaf (*Abutilon theophrasti* Medik.), common sunflower (*Helianthus annuus* L.), and wild mustard (*Sinapsis arvensis* L.) have been extensively reported and can exceed 73% (Mesbah et al. 1994, 1995; Schweizer 1981, 1983; Schweizer and Bridge 1982; Schweizer and Lauridson 1985). These weed species grow tall and completely shade the sugarbeet canopy, whereas wild buckwheat has a trailing and twinning growth habit. In spite of the growth habit, wild buckwheat has been reported to reduce crop yields, especially where it occurs in dense stands. Yield reductions due to wild buckwheat competition have been reported in wheat (*Triticum aestivum* L.) (Boström et al. 2003; Messersmith and Nalewaja 1969; Nalewaja 1964), flax (*Linum usitatissimum* L.) (Gruenhagen and Nalewaja 1969), and barley (*Hordeum vulgare* L.) (Friesen and Shebeski 1960). Although these studies clearly demonstrate that wild buckwheat competition can reduce yields particularly in small grains, it is unclear if it can be an effective competitor with sugarbeet based on its growth habit.

Duration of weed interference can adversely affect crop yield. Consequently, a better understanding of the critical period of weed control (CPWC) is very important in determining the effect of weed interference in crops. According to Knezevic et al. (2002), the CPWC represents the time interval between two separately measured crop-weed

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competition components: (1) the critical timing of weed removal (CTWR) or the maximum amount of early-season weed competition that the crop can tolerate before it suffers irrevocable yield reduction, and (2) the critical weed-free period (CWFP) or the minimum weed-free period required from the time of planting to prevent unacceptable yield reductions. The CTWR represents the period of time when weed control must be begin to protect potential yield (Knezevic et al. 2003). The crop–weed competition components are commonly related to days after emergence (DAE) (Norsworthy and Oliveira 2004), weeks after planting (Everman et al. 2008), crop development stage (Halford et al. 2001), or growing degree days (Bukun 2004). Environmental conditions, crop genetics, and cultural practices, including tillage, fertilization, seeding rate, and row spacing, are factors that can influence these crop–weed competition components by affecting weed species composition, weed density, time of weed emergence relative to the crop, and crop and weed growth (Norsworthy and Oliveira 2004). Mesbah et al. (1994, 1995) reported yield reduction as a result of duration of interference effects of kochia, green foxtail [*Setaria viridis* (L.) Beauv.], wild mustard, and wild oat (*Avena fatua* L.) on sugarbeet. No studies, however, have been conducted to evaluate the effect of duration of wild buckwheat interference on sugarbeet.

The objective of this study was to determine: (a) the effect of wild buckwheat density on sugarbeet root yield and sucrose content, and (b) the effect of duration of wild buckwheat interference on sugarbeet sucrose content and the CTWR.

Materials and Methods

Field Operations. Field experiments evaluating wild buckwheat interference in sugarbeet were conducted in 2006 and 2007 at the Powell Research and Extension Center (PREC) in Wyoming. The soil type was a Garland loam (fine-loamy over sandy or sandy-skeletal, mixed, superactive, mesic Typic Haplargids) with pH 7.6 and 1.3% organic matter. Experimental plots were located in fields that were in barley production the previous year. Fields were moldboard plowed and leveled in the fall after barley harvest. Urea was broadcast applied and incorporated at 112 kg/ha of N, and fields subsequently bedded on 56 cm rows on March 28, 2006 and March 26, 2007. Wild buckwheat seeds from Fargo, ND and seeds harvested from the PREC fields in the summer of 2006 were planted on April 22, 2006 and May 4, 2007, respectively, on sugarbeet beds prior to planting the sugarbeet crop using a one-row manual cone planter. Sugarbeet cultivar 'Treasure' was planted on April 24, 2006 and May 10, 2007 at the rate of 111,000 seeds/ha. Plots were subsequently side-dressed with 135 kg/ha of N using urea ammonium nitrate applied with a spoke wheel applicator. Cultivation was done on June 17, 2006 and June 25, 2007 to control weeds between the rows using a six-row cultivator with 38 cm sweeps. Plots were kept free of other weeds by hand removal throughout the entire growing season. All plots were furrow-irrigated during the growing season to optimize growing conditions and ensure that moisture was not a limiting factor.

Individual plots for the weed density and duration of interference studies were established immediately after sugarbeet and wild buckwheat emergence for both studies (sugarbeet and wild buckwheat emerged at the same time in both years). Experimental plots consisted of three sugarbeet rows 7.6 m long and spaced 56 cm apart arranged in a randomized complete block design with four replications for both studies.

Density Study. The density study was conducted using an additive design whereby sugarbeet density was constant with a variable wild buckwheat density (Harper 1977; Park et al. 2003). Densities of 0, 6, 12, 18, 24, and 30 wild buckwheat plants per m of row were established in an 8-cm band over the sugarbeet row both years by hand thinning after emergence. Sugarbeet was harvested from the center row of each plot on September 28, 2006 and October 1, 2007, using a one row mechanical sugarbeet lifter. Sugarbeet root fresh weights were measured in the field, and a subsample was sent for quality analysis at the Western Sugar Tare Laboratory in Billings, MT.

Duration of Interference. Studies were established in a manner similar to the density study. Shortly after emergence, wild buckwheat was thinned to a density of 18 wild buckwheat plants per m in an 8-cm band over the sugarbeet row both years. Wild buckwheat was allowed to compete with sugarbeet for 0, 36, 50, 64, 78, 92, and 106 DAE before hand removal. Full season duration of interference of wild buckwheat was included at the same density. Sugarbeet harvest was similar to the procedure described in the density study.

Data Analysis. All data collected were subjected to ANOVA using the MIXED procedure in SAS[1] at the 5% level of significance to assess the effect of wild buckwheat density and duration of interference on sugarbeet yield. Sugarbeet yield components included percent sucrose, root yield, and sucrose yield. Sucrose yield was a function of root yield based on percent sucrose. For both the density and duration studies, year was considered a random variable, and the density or duration main effect were tested for error associated with appropriate year by density or duration of interference interaction (McIntosh 1983).

Sugarbeet root and sucrose yield loss was calculated as $1 - (Y_{obs} / Y_{wf})$ where Y_{wf} was the average yield in weed-free plots and Y_{obs} the observed yield within a given density. The effect of wild buckwheat density on sugarbeet yield loss was described using the rectangular hyperbolic model (Cousens 1985):

$$Y = Y_{wf}(1 - Id/100(1 + Id/A)) \qquad [1]$$

where Y is sugarbeet yield (Mg/ha), Y_{wf} is the estimated weed-free sugarbeet yield, d is the wild buckwheat density, I is the percentage sugarbeet yield loss per unit wild buckwheat density as density approaches zero, and A is the asymptote or percentage sugarbeet yield loss as wild buckwheat density approaches infinity. Equation 1 can also be expressed in terms of yield loss:

$$Y_L = Id/(1 + Id/A) \qquad [2]$$

Table 1. Relationship between percentage sugarbeet yield loss and wild buckwheat density.[a]

	Parameter estimates		
Sugarbeet yield	Y_{wf}	I	A
	Mg/ha	%	
Root	71.1(3.65)	5.9(1.93)	63.8(12.17)
Sucrose	12.1(0.67)	6.1(2.22)	61.0(11.94)

[a] Data was fit to the model Equation 1, where Y_{wf} is the estimated weed free yield, I is the percent yield loss per unit density as wild buckwheat density approaches zero, and A is the asymptotic yield loss as wild buckwheat density approaches infinity. Standard errors are in parenthesis.

where Y_L is the percentage sugarbeet yield loss (% weed-free yield), and d, I, and A are the same as in Equation 1. Equations 1 and 2 were fit to data using the drc package (Ritz and Streibig 2005) of the open source language R.[2]

A four parameter logistic model was used to describe the effect of increasing duration of wild buckwheat interference on relative yield of sugarbeet:

$$Y = c + (d - c)/1 + \exp[b(\log(T) - \log(e))] \qquad [3]$$

where Y is the relative root yield (% season-long weed-free yield), T is time expressed as DAE, b is the slope at the inflection point, c is the lower limit, d is the upper limit, and e is the number of DAE where the inflection point occurs. Equation 4 was also fit to data using the drc package of R.

Results and Discussion

Season-Long Interference from Various Densities of Wild Buckwheat. Wild buckwheat density had no effect on percent sucrose. However, percent sucrose was significantly higher in 2007 compared with 2006 (17.6 and 16.6%, respectively). Differences observed between years were probably related to environmental conditions during the growing season. Similarly, competition from densities of common lambsquarters (Schweizer 1983), Powell amaranth (Schweizer and Lauridson 1985), kochia and green foxtail (Mesbah et al. 1994), and wild mustard and wild oat (Mesbah et al. 1995) had no effect on percent sucrose. However, Schweizer and Bridge (1982) reported reduction in percent sucrose with increasing densities of velvetleaf and common sunflower, indicating that the effect of weed interference on percent sucrose is influenced by weed species.

The interaction between year and wild buckwheat density was not significant for sugarbeet root and sucrose yield loss; therefore, the predicted yield loss represents data averaged over both years. The response of sugarbeet yield to wild buckwheat density was significant and fit the rectangular hyperbolic model (Equation 1). Estimated yield in the weed-free plots were 71.1 and 12.1 Mg/ha for root and sucrose yield, respectively (Table 1). The model was constrained to an asymptotic percentage yield loss, A lying between 0 and 100% because yield loss cannot exceed 100% (Cousens 1985). The maximum root and sucrose yield loss due to interference of wild buckwheat was estimated to be 63.8 and 61.0% for root and sucrose yield loss, respectively. The parameter of interest

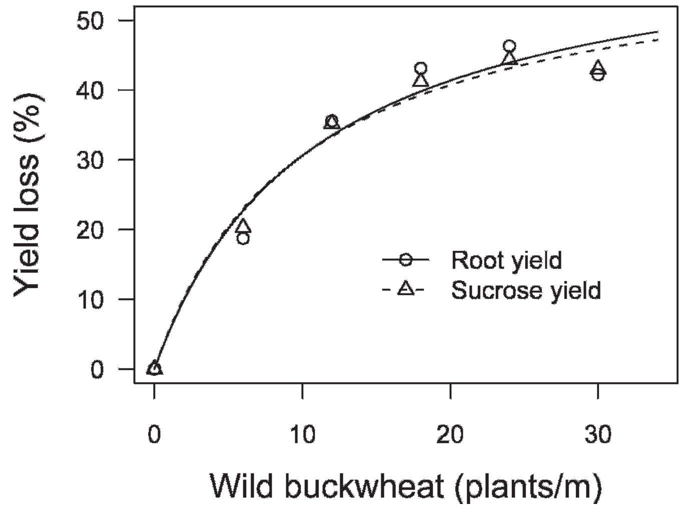

Figure 1. Effect of wild buckwheat density on sugarbeet yield.

I, was estimated to be 5.9% for root and 6.1% for sucrose yield loss. This parameter is used as an indicator of potential weed competitiveness. Based on this value, predicted root and sucrose yield loss from season-long interference of one wild buckwheat plant per m of sugarbeet row was 6%. Sugarbeet root and sucrose yield generally decreased with increasing wild buckwheat density (Figure 1). Predicted yield loss from season-long interference of 6, 12, 18, 24, and 30 wild buckwheat plants per m of sugarbeet row was 23, 33, 40, 44, and 47% for root yield, and 23, 33, 39, 43, and 46% for sucrose yield, respectively. The predicted losses for root and sucrose yield were similar because wild buckwheat density had no effect on percent sucrose, and sucrose yield is a function root yield and percent sucrose content. Schweizer (1983) reported that at densities of 0.2, 0.4, 0.6, and 0.8 common lambsquarters plants per m of sugarbeet row, sugarbeet root yields were reduced 13, 29, 38, and 48%, respectively, and sucrose yield were reduced 11, 27, 37, and 46%, respectively. Similarly, Powell amaranth densities of 0.2, 0.4, 0.6, and 0.8 plants per m of sugarbeet row reduced sugarbeet root yields 8, 14, 24, and 25%, respectively, and sucrose yield 7, 13, 23, and 24%, respectively (Schweizer and Lauridson 1985). Schweizer and Bridge (1982) studied interference of sunflower and velvetleaf in sugarbeet, and established that at densities of 0.2, 0.4, 0.6, and 0.8 sunflower plants per m of sugarbeet row, root yields were reduced 40, 52, 67, and 73%, respectively. At similar densities of velvetleaf, root yields were reduced 14, 17, 25, and 30%, respectively. Sugarbeet yield loss due to wild buckwheat interference was less than that of previously reported broadleaf weeds but still significant because of the high value of the sugarbeet crop. The greater reduction in yield as a result of competition from other broadleaf weeds is attributed to their rapid growth and large size that enable them to completely shade the sugarbeet canopy during the growing season. Yield reduction due to competition from dense stands of wild buckwheat has been reported in small grains (Boström et al. 2003; Friesen and Shebeski 1960; Gruenhagen and Nalewaja 1969; Messersmith and Nalewaja

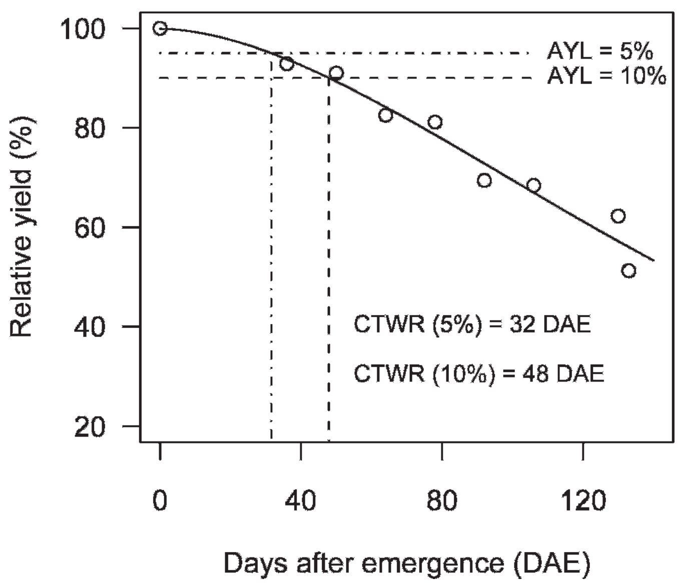

Figure 2. The influence of wild buckwheat duration of interference on relative sugarbeet root yield.

1969; Nalewaja 1964). The competitive ability of wild buckwheat results from its climbing habit, which allows the plant to obtain light while growing in stands of grain or other taller crops that might otherwise shade it (Hume et al. 1983). In this study, wild buckwheat was able to climb and shade sugarbeet foliage early in the season, and as the density of wild buckwheat increased, light could have become more limited for sugarbeet, thus resulting in decreased yield. Additionally, wild buckwheat has the ability to spread horizontally and quickly cover bare ground, enabling it to maximize light and soil nutrient gathering efficiency (Hume et al. 1983) compared with sugarbeet that has an initial slow growth and development (Milford 1973; Scott and Wilcockson 1976).

Critical Timing of Wild Buckwheat Control. Percent sucrose was not affected by duration of wild buckwheat interference just as in the density study, and averaged 17.3% over both years. Similarly, duration of interference of kochia and green foxtail (Mesbah et al. 1994), as well as wild mustard and wild oat (Mesbah et al. 1995), had no effect on percent sucrose. However, Weatherspoon and Schweizer (1969) reported a reduction in percent sucrose as duration of kochia competition increased, suggesting that the effect of duration of weed interference on percent sucrose varies with different weed species.

No significant year by duration of interference interaction was observed for relative sugarbeet root yield; therefore, data were combined over years for analysis. Relative root yield data are expressed as a percentage of the season-long wild buckwheat-free yield. The four-parameter logistic model (Equation 3) provided the best fit for the weedy period (Figure 2) demonstrating that wild buckwheat duration of interference has significant effect on sugarbeet root yield. Coefficients for the parameters used to fit the logistic model are listed in Table 2.

Table 2. Coefficient estimates to determine the effect of timing wild buckwheat removal on relative sugarbeet root yield using a logistic model.[a]

Coefficient			
b	*c*	*d*	*e*
1.78(1.42)	−32.26(361.94)	99.92(4.68)	197.01(499.23)

[a] Data fit to Equation 3, where *b* is the slope at the inflection point, *c* is the lower limit, *d* is the upper limit, and *e* is the number of DAE where the inflection point occurs. Standard errors are in parenthesis.

The acceptable yield loss (AYL) levels used to predict the CTWR were 5 and 10%. These can be adjusted depending on weed management cost and expected economic returns (Knezevic et al. 2002). The model illustrated that sugarbeet yield loss due to wild buckwheat interference occurred throughout the season and increased with time (Figure 2). The CTWR to prevent 5 and 10% root yield loss was 32 and 48 d, respectively. The relatively large CTWR indicates that sugarbeet exhibited some early-season tolerance to wild buckwheat at the density used in the study. In comparison, the CTWR of mixed weed populations in other crops are shorter. Halford et al. (2001) observed that at 2.5% AYL the CTWR in corn (*Zea mays* L.) was 14 to 18 DAE and depended on location and weed densities. Norsworthy and Oliveria (2004) observed that the CTWR at 5% AYL for corn was 5 to 21 DAE depending on location. The CTWR for soybean at 2.5% AYL was 13 to 40 DAE depending on location (Halford et al. 2001).

Sugarbeet root yield reduction as a result of duration of interference from several weed species in sugarbeet has been reported. Weatherspoon and Schweizer (1969) reported that sugarbeet root yields were reduced by 11 Mg/ha with an additional week of kochia competition. Mesbah et al. (1994) reported that the minimum duration of time that 0.5 kochia and three green foxtail [*Setaria viridis* (L.) Beauv.] plants per m of row can interfere with sugarbeet before yield reduction was 25 DAE, and similarly, 0.8 wild mustard and one wild oat plant per m of row required a minimum of 11 DAE of sugarbeet to cause yield reduction (Mesbah et al. 1995).

The results show that wild buckwheat interference can cause significant yield losses in sugarbeet despite its trailing and twining growth habit. Season-long interference of one wild buckwheat plant per m of sugarbeet row can result in up to 6% yield loss, indicating that it can be detrimental to yields when it emerges earlier or at the same time as the crop. Higher densities of wild buckwheat can further increase yield loss. In addition, wild buckwheat can be allowed to compete with sugarbeet for longer periods when the weed occurs at densities and environmental conditions similar to that under which this study was conducted. This underscores the importance of basing weed control strategies on weed population present in the field. The critical timing of wild buckwheat removal is important for making decisions on the appropriate timing of control. The CTWR can also be utilized to attain efficient use of herbicides and other weed management tools for wild buckwheat control in sugarbeet by basing the timing of herbicide application on it.

Sources of Materials

[1] Statistical Analysis Systems®, version 9.1.3, 2005. SAS Institute Inc., SAS Campus Drive, Cary, NC 27513.

[2] R version 2.8.1. The R Foundation for Statistical Computing, Vienna, Austria.

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