Venice Mallow (*Hibiscus trionum*) 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 Venice mallow densities and duration of interference on sugarbeet. Sucrose concentration was not affected by Venice mallow interference. The effect of Venice mallow density on sugarbeet root and sucrose yield loss was described by the rectangular hyperbola model. Root and sucrose yield loss increased as Venice mallow density increased. The estimated asymptote, *A* (percent yield loss as density approaches infinity) was 61% for both root and sucrose yield loss, and the estimated parameter, *I* (percent yield loss per unit weed density as density approaches zero) was 6% for both root and sucrose yield loss. Sugarbeet root yield decreased as the duration of Venice mallow interference increased. The critical timing of weed removal to avoid 5 and 10% root yield loss was 30 and 43 d after sugarbeet emergence, respectively. Results show that Venice mallow is competitive with sugarbeet implying that it should be managed appropriately to reduce negative effects on yield and prevent seed bank replenishment and re-infestation in subsequent years.

Nomenclature: Venice mallow, *Hibiscus trionum* L. HIBTR; sugarbeet, *Beta vulgaris* L.
Key words: Competition, critical period, length of competition, timing of removal, weed density, percent sucrose.

Venice mallow is a troublesome annual broadleaf weed in many irrigated and dryland crops worldwide (Eaton et al. 1973, 1976; Firehun and Tamado 2006; Walker et al. 2005; Westra et al. 1990). The prevalence of Venice mallow in these cropping systems is probably attributable to its high seed production and tolerance of various management techniques, which allow seed reserves to carry over from year to year (Westra et al. 1996). Venice mallow's temporal emergence pattern, persistence over a range of soil disturbances, and rapid and aggressive growth have also contributed to its success in cropping systems (Teo-Sherrell et al. 1996). Venice mallow is a low-growing plant that is able to branch profusely under low crop density, allowing it to utilize available light, moisture, and nutrients (Stubbendieck et al. 2003). In addition, it is a facultative long-day plant, and temperature interacts with lighting to affect flowering. Warner and Erwin (2001) reported that Venice mallow plants grown under continuous lighting required 61, 43, and 36 d to anthesis at 15, 20, and 25 C, respectively, indicating that they can be very competitive for light during warmer periods of the year.

The importance of Venice mallow has increased in the Bighorn Basin of Wyoming, especially in sugarbeet production. Within the Bighorn Basin, Venice mallow emergence occurs early in the season and continues throughout the season. In sugarbeet, early-emerging weeds are recognized to be more competitive because of the crop's slow growth and development early in the season (Milford 1973; Schweizer and May 1993; Scott and Wilcockson 1976).

The weed density effects of Venice mallow have been studied in several crops. Eaton et al. (1973, 1976) reported up to 51% soybean [*Glycine max* (L.) Merr.] yield reduction from Venice mallow competition. Venice mallow densities of 15 and 300 plants/m^2 reduced yields of seeded and transplanted onions (*Allium cepa* L.) by 78 and 53%, respectively (Westra et al. 1990). However, Chandler (1977) reported no yield reduction in 102-cm row spaced cotton (*Gossypium hirsutum* L.) at densities of up to 64 Venice mallow plants per 12 m of crop row. In addition, interspecific cotton competition resulted in reduction of Venice mallow dry matter production. These studies suggest that interspecific effects of Venice mallow on a tall-stature crop such as cotton are quite low. Information about interference of low-statured weeds such as Venice mallow in sugarbeet is currently scarce. However, sugarbeet yield losses due to interference from tall growing weed species such as 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 (*Sinapis arvensis* L.) have been extensively reported (Mesbah et al. 1994, 1995; Schweizer 1981, 1983; Schweizer and Bridge 1982; Schweizer and Lauridson 1985). Therefore, based on its growth habit, it was unclear how competitive Venice mallow would be with sugarbeet.

The critical period of weed control (CPWC) is important in determining the effect of weed interference in crops (Zimdahl 2004). The CPWC is described by the time interval between two separately measured crop–weed 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 or the minimum weed-free period required from the time of planting to prevent unacceptable yield reductions (Knezevic et al. 2002). The CTWR represents the period when weeds start having negative effects on the crop due to limitation of resources that both the crop and weed require for growth. Several factors such as environmental conditions, crop genetics, and cultural practices including tillage, fertilization, seeding rate, and row spacing may influence the CPWC by affecting weed species composition, weed density, time of weed emergence relative to the crop, and crop and weed growth (Norsworthy and Oliveira 2004). An understanding of the CPWC provides a basis for planning effective weed

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control strategies in crops. Critical period is commonly related to either days after emergence (DAE) (Norsworthy and Oliveira 2004) or growing degree days (Bukun 2004). Although Mesbah et al. (1994, 1995) reported duration of interference effects of kochia, green foxtail [*Setaria viridis* (L.) Beauv.], wild mustard, and wild oat (*Avena fatua* L.) on sugarbeet, no studies have been conducted to evaluate the effect of duration of Venice mallow interference on sugarbeet in the absence of other weeds.

The objectives of this study were to determine (1) the effect of Venice mallow density on sugarbeet root yield and sucrose content, and (2) the effect of duration of Venice mallow interference on sugarbeet sucrose content and the CTWR.

Materials and Methods

Field Operations. Field experiments evaluating Venice mallow 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 Haplargid) with pH 7.6 and 1.3% organic matter. The experimental plots were located in fields that were in barley (*Hordeum vulgare* L.) production the preceding year. Fields were moldboard plowed and leveled in the autumn following barley harvest. Urea was broadcast applied and incorporated at the rate of 112 kg/ha of N, and fields subsequently bedded on 56-cm rows on March 28, 2006, and March 26, 2007. Venice mallow seeds collected at the PREC fields in late summer of 2005 and 2006 were planted on the bedded fields on April 22, 2006, and May 4, 2007, using a one-row manual cone planter prior to planting sugarbeet. 'Treasure' sugarbeet was planted on April 24, 2006, and May 10, 2007, at the rate of 111,000 seeds/ha. The 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 also 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 Venice mallow emergence for both studies (sugarbeet and Venice mallow 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 three replications for both studies.

Density Study. The density study was conducted using an additive design whereby sugarbeet density was constant with a variable Venice mallow density (Harper 1977; Park et al. 2003). Densities of 0, 6, 12, 18, 24, and 30 Venice mallow plants/m 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, the Venice mallow was thinned to a density of 18 Venice mallow plants/m in a 8-cm band over the sugarbeet row both years. Venice mallow was allowed to compete with sugarbeet for 0, 36, 50, 64, 78, 92, and 106 DAE before hand removal. Full season Venice mallow duration of interference was included at the same density. Sugarbeet harvest was similar to the procedure described in the density study.

Data Analysis. Analysis of variance was performed on all data using the MIXED procedure in SAS (SAS Institute 2007) at 5% level of significance to assess the effect of Venice mallow density and duration of interference on sugarbeet yield components. Sugarbeet yield components included percent sucrose, root yield, and sucrose yield. Sucrose yield was a function of root yield based on percent sucrose. For the density study, year was considered a random variable, and the density main effects were tested for error associated with the appropriate year by density interaction, and similarly, year was considered a random variable for the duration of interference study, and duration main effects were tested for error associated with the appropriate year by 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 relationship between sugarbeet yield and Venice mallow density was described using a rectangular hyperbola model (Cousens 1985):

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

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

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

where Y_L is the percent sugarbeet yield loss (% sugarbeet yield free of Venice mallow), and d, I, and A are the same as in Equation 1. Equations 1 and 2 were fitted to data using the drc package (Ritz and Streibig 2005) of the open source language R (R version 2.8.1; R Development Core Team 2008).

A four-parameter logistic model was fitted to assess the effect of duration of Venice mallow interference on relative sugarbeet yield:

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

where Y is the relative root yield (% season-long sugarbeet root yield free of Venice mallow), T is time expressed as DAE, b is the slope at the inflection point, c is the lower limit of relative root yield, *d* is the upper limit of relative root yield, and *e* is the number of DAE where the inflection point occurs. Equation 3 was also fitted to data using the drc package of R.

Results and Discussion

Venice Mallow Density. Percent sucrose was significantly higher in 2007 compared to 2006 (17.5 and 16.9%, respectively). Differences observed between years probably resulted from prevailing environmental conditions during the growing season. Venice mallow density affected sugarbeet root and sucrose yield but had no effect on percent sucrose. Previous research has shown that competition from varied 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. In contrast, Schweizer and Bridge (1982) reported reduction in percent sucrose with increasing densities of velvetleaf and common sunflower. This shows that the effect of weed interference on percent sucrose is probably influenced by weed species and prevailing environmental conditions.

There was no significant year by Venice mallow interaction for either sugarbeet root or sucrose yield loss data. Therefore, data from the two years were combined for analysis. In the absence of Venice mallow, root and sucrose yield were estimated to be 68 and 11 Mg/ha, respectively (Figure 1). The response of sugarbeet yield to Venice mallow density was significant and fit the hyperbolic model (Equation 1). The model was constrained to an asymptotic percentage yield loss, *A*, lying between 0 and 100% since yield loss can never exceed 100% (Cousens 1985). Maximum root and sucrose yield loss due to interference of Venice mallow was estimated to be 61%. The *I* parameter, which is an indicator of the potential weed competitiveness, was estimated to be 6% for both root and sucrose yield loss. Based on this value, predicted root and sucrose yield loss from season-long interference of one Venice mallow plant per meter of sugarbeet row was 6%. Root and sucrose yield loss increased with Venice mallow density. Predicted root yield loss from season-long interference of 6, 12, 18, 24, and 30 Venice mallow plants per meter of sugarbeet row was 23, 33, 39, 42, and 45%. Since percent sucrose content was unaffected by Venice mallow density, sucrose yield loss estimates were similar.

At densities of 0.2, 0.4, 0.6, and 0.8 common lambsquarters plants per meter of sugarbeet row, sugarbeet root yields were reduced 13, 29, 38, and 48%, respectively, and sucrose yield was reduced 11, 27, 37, and 46%, respectively (Schweizer 1983). Powell amaranth densities of 0.2, 0.4, 0.6, and 0.8 plants per meter 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 meter 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. The greater yield reduction from these weeds

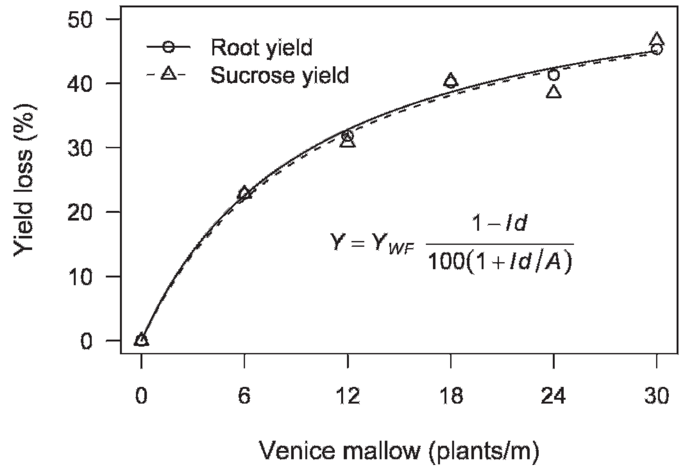

Figure 1. Effect of Venice mallow density on sugarbeet yield. Equation 1, where *d* is the Venice mallow weed density used to predict the relationship between sugarbeet yield and Venice mallow density. Parameter estimates and standard errors were Y_{wf} = 68.1 (3.23), I = 5.8 (2.53), and A = 61.3 (12.61) for root yield; Y_{wf} = 11.4 (0.52), I = 5.5 (2.37), and A = 61.0 (12.70) for sucrose yield.

compared to Venice mallow is attributable to their ability to grow taller and completely shade the sugarbeet canopy during the growing season. Venice mallow has been reported to exhibit weak interspecific competition in crops as tall or taller than itself (Westra et al. 1990), probably explaining the lower reduction in sugarbeet yield in comparison to taller weeds used in previous studies.

These results indicate that despite its low stature, season-long Venice mallow interference can significantly reduce sugarbeet yield. However, these yield losses are lower than those reported for interference from other broadleaf weeds commonly associated with sugarbeet. Sugarbeet is a high value crop in which yield losses should be minimized, and therefore growers should manage Venice mallow infestations appropriately to diminish root yield losses and prevent soil seed bank replenishment and subsequent re-infestation in subsequent years.

Critical Time for Venice Mallow Removal. Percent sucrose was significantly higher in 2007 compared to 2006 (17.9 and 16.2%, respectively) probably due to differences in environmental conditions, however, duration of interference did not affect the percent sucrose in either year, which is similar to results observed in the density study. Similar observations have been reported for kochia and green foxtail (Mesbah et al. 1994), as well as wild mustard and wild oat (Mesbah et al. 1995) duration of interference in sugarbeet. 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 and prevailing environmental conditions.

The year by duration of interference interaction effect was not significant for relative sugarbeet root yield so consequently data were combined over years for analysis. The four-parameter logistic model (Equation 3) provided the best fit for the CTWR. The CTWR due to Venice mallow interference increased in sugarbeet as predetermined acceptable

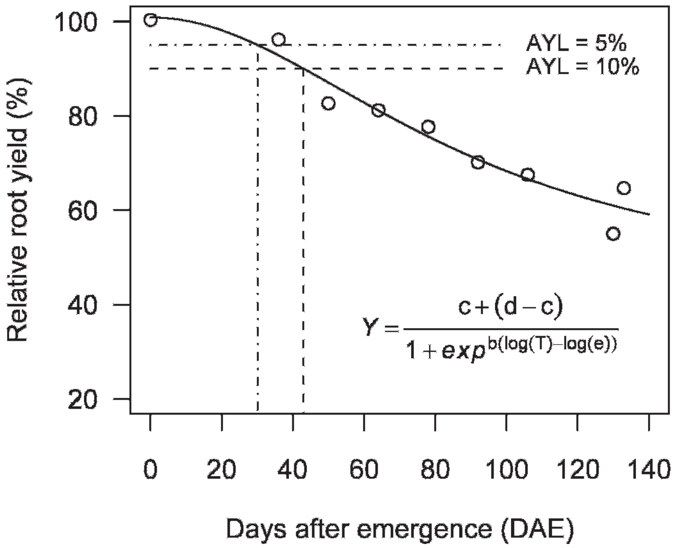

Figure 2. The influence of Venice mallow duration of interference on relative sugarbeet root yield. Equation 3, where T is the days after sugarbeet emergence (DAE) used to predict Venice mallow interference on relative sugarbeet root yield. Parameter estimates and standard errors were $b = 2.01$ (1.10), $c = 41.92$ (35.86), $d = 100.86$ (4.04), and $e = 90.04$ (58.52).

yield loss (AYL) level increased (Figure 2). Using an AYL level of 5 and 10%, the CTWR for Venice mallow in sugarbeet was estimated to be 30 and 43 DAE, respectively. Determination of AYL depends on the cost of weed management in relation to the yield benefit achieved by the grower. Consequently, a decision on the AYL based on the value of a crop needs to be taken before the determination of CTWR. The long CTWR indicates sugarbeet exhibited some early-season tolerance to Venice mallow at the density used in the study. However, it is likely that the CTWR will be shortened if Venice mallow occurs at densities greater than 18 plants per meter of sugarbeet row.

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 25% with an additional week of kochia competition. However, most fields have mixed populations of weed species. Mesbah et al. (1994) evaluated the effects of kochia and green foxtail on sugarbeet. They determined that the minimum duration of time that 0.5 kochia and 3 green foxtail plants per meter of row can interfere with sugarbeet before yield reduction was 3.5 wk after emergence (WAE). Similarly, 0.8 wild mustard and 1 wild oat plant/m of row required a minimum of 1.6 WAE of sugarbeet to cause yield reduction (Mesbah et al. 1995). Eaton et al. (1973) reported soybean yield reduction of 13% from a natural stand of 215 Venice mallow plants/m^2 after 30 d of competition, and 50% yield reduction from 110 d of competition. Despite the longer CTWR for sugarbeet in the presence of Venice mallow reported in this study, economic yield losses will occur if left uncontrolled, and thus control measures should be implemented to prevent yield loss and forestall seed production by Venice mallow plants and prevent their contribution to the soil seed bank.

These studies provide new information on the effect of Venice mallow interference on sugarbeet. Season-long interference of one Venice mallow plant per meter of sugarbeet row can result in up to 6% yield loss indicating that even though it has a low-stature growth habit, it is detrimental to yields especially where it occurs in higher densities. Since Venice mallow is a prolific seed producer, it should be managed even at low densities to prevent replenishment of the soil seed bank for re-infestation in subsequent years. In addition, sugarbeet can tolerate Venice mallow interference for 30 to 43 d depending on the AYL a grower is prepared to accept, suggesting that control measures should commence before this period to prevent detrimental effects on yield. The determination of the AYL will depend on the cost of weed control in relation to the yield benefit realized. Knowledge of the competitive ability of Venice mallow and the CTWR provides valuable information upon which to base and develop management guidelines or recommendations specifically targeting infestation of Venice mallow in sugarbeet. The CTWR is not only essential for making decisions on the appropriate timing of Venice mallow control but is also important in achieving efficient use of herbicides and other weed management tools. Weeds seldom occur as single-species monocultures. Consequently the results of this study should be used in conjunction with other management tools especially where there are mixed weed populations.

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