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Hairy Nightshade Critical Interference Period in Potatoes

Pamela J. S. Hutchinson*

Field research trials were conducted in Idaho at the Aberdeen Research and Extension Center in 2006 and 2007 to determine the critical interference period of hairy nightshade in potatoes. 'Russet Norkotah' variety was planted both years in plots three rows wide by 12 m long. When the potatoes had emerged, one- to two-leaf hairy nightshade plants that had been germinated and grown in the greenhouse were transplanted at a 2 m^{-1} row density and allowed to grow for 10, 20, 30, or 40 d after emergence (DAE) before removal, or the potatoes were maintained weed-free for 0, 10, 20, 30, or 40 DAE before transplanting. Potatoes were harvested from the center row at the end of each growing season and yield and grade was determined. Russet Norkotah is a small-canopied potato variety and often does not completely close canopy in Idaho. Russet Norkotah U.S. No. 1 and total tuber yield were similar to weed-free yield when hairy nightshade transplanting was delayed up to 22 or 24 DAE, respectively, or planted at emergence and allowed to remain for only 6 or 11 d, respectively. Otherwise, yield decrease was 5% or greater. Therefore, the critical weed-free period for Russet Norkotah potato U.S. No. 1 or total tuber yields was 6 to 22 or 11 to 24 DAE, respectively.
Nomenclature: Hairy nightshade, *Solanum physalifolium* Rusby SOLSA; potato, *Solanum tuberosum* L. 'Russet Norkotah'.
Key words: Time of removal, weed-free period.

Se realizaron estudios de campo en Idaho en el Centro de Investigación y Extensión de Aberdeen en 2006 y 2007, para determinar el período crítico de interferencia de *Solanum physalifolium* en papa. La variedad 'Russet Norkotah' fue plantada en ambos años en lotes de tres hileras de ancho y 12 m de largo. Cuando las papas habían emergido, plantas de *S. physalifolium* de una a dos hojas, que habían sido germinadas y crecidas en invernaderos, fueron trasplantadas a una densidad de 2 m^{-1} y fueron crecidas por 10, 20, 30, ó 40 días después de la emergencia (DAE) antes de ser removidas, o las papas fueron mantenidas libres de malezas por 0, 10, 20, 30, ó 40 DAE antes del trasplante. Se cosecharon papas de la hilera central al final de cada temporada de producción y se determinó el rendimiento y la calidad. La variedad Russet Norkotah es de dosel pequeño y a menudo este dosel no cierra completamente en Idaho. Los rendimientos U.S. No. 1 y total de esta variedad fueron similares al testigo libre de malezas cuando el trasplante de *S. physalifolium* se atrasó hasta 22 ó 24 DAE, respectivamente, o cuando se trasplanto al momento de la emergencia del cultivo y se dejó solamente por 6 ó 11 d, respectivamente. De otra manera, la reducción del rendimiento fue 5% o mayor. Así, el período crítico libre de malezas para el rendimiento U.S. No. 1 y total de papa Russet Norkotah fue 0 a 66 y 11 a 24 DAE, respectivamente.

Hairy nightshade is a problem weed in potatoes grown in the Pacific Northwest (PNW) and other areas in the United States and Canada (Blackshaw 1991; Hutchinson and Eberlein 2003; Hutchinson et al. 2011). It is the most common of the annual nightshades found in the PNW (Miller and Parker 2006; Ogg and Rogers 1989; Quakenbush and Andersen 1984). There are at least six herbicides that can provide hairy nightshade control in potato including dimethenamid-p, EPTC, flumioxazin, fomesafen, linuron, and rimsulfuron (Alvarez and Hutchinson 2005; Eberlein et al. 1992, 1994; Hutchinson 2005, 2007a, b; Hutchinson and Eberlein 2003; Hutchinson et al. 2003, 2004, 2005a,b, 2014). Only one of these, rimsulfuron, is labeled for POST applications in potato. Although commonly used potato desiccants can provide late-season hairy nightshade control, berry production is not affected, seed germination is not reduced by more than 10%, and dense hairy nightshade populations still can interfere with potato harvest (Hutchinson et al. 2006; Miller and Parker 2006). Ogg and Dawson (1984) have observed high infestations of hairy nightshade that emerged in potato fields as late as September after the potato vines had begun to senesce and die.

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Season-long hairy nightshade control can be difficult for many reasons: its seeds do not require light for germination and it can germinate over a wide range of temperatures and soil pH; emergence can occur throughout the growing season; and plants can produce flowers and seed-containing berries until the end of the growing season, with viable seed production occurring as soon as 4 to 5 wk after flowering and as late as 6 to 7 wk before a killing frost (Basset and Munro 1985; Blackshaw 1991; Hermanutz and Weaver 1991; Hutchinson and Eberlein 2003; Ogg and Dawson 1984; Ogg and Rogers 1989; Peachy and Mallory-Smith 2007; Quakenbush and Andersen 1984; Roberts and Boddrell 1983; Zhou et al. 2005). Hairy nightshade has been known to produce as many as 300,000 seeds m^{-2} when population density was approximately 30 plants m^{-2} in dry bean (*Phaseolus vulgaris* L.) and when growing at densities of 1 to 3 plants m^{-1} row in Russet Norkotah potato, more than 45,760 seeds m^{-1} row (Blackshaw 1991; Hutchinson et al. 2011). Hairy nightshade also serves as an alternate host for insects, nematodes, and plant pathogens in potato (Allen and Davis 1982; Alvarez and Hutchinson 2005; Alvarez and Srinivasan 2005; Alvarez et al. 2003; Eberlein et al. 1991; Miller and Parker 2006; Nolte et al. 2003; Ogg and Rogers 1989; Olanya et al. 2009; Srinivasan et al. 2006).

The critical period of weed interference is the time span between the maximum weed-infested period or length of time that weeds emerging with a crop can remain before they begin to cause crop yield reductions and the minimum weed-free period, or length of time a crop must be weed-free after planting in order to prevent yield losses (Radosevich and Holt 1984; Singh et al. 1996; Zimdahl 1988, 2004). The maximum weed-infested and minimum weed-free components are determined by measuring crop yield loss as a function of successive times of weed removal and weed emergence, respectively (Weaver et al. 1992).

Researchers have shown that weeds do not have to be present season-long, but a critical weed free period must be maintained for a length of time at the beginning of the season (Dawson 1964; Fennimore et al. 1984; Keeley and Thullen 1989; Nelson and Thoreson 1981). Liebman et al. (1996) stated that the few weeds that emerge early in the potato growing season and survive control operations can result in large tuber yield reductions and economic losses. Eberlein et al. (1997) and others (Jaiswal and Lal 1996) state that timely control of weeds can increase potato yields as much as 50%. More specifically, VanGessel and Renner (1990) found in a Michigan field study that 1 barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.] or redroot pigweed (*Amaranthus retroflexus* L.) plant m^{-2} seeded at the same time as, but emerging before potato, and competing season-long, reduced marketable tuber yield 19 or 33%, respectively. Another study showed that the greatest reduction in tuber yield occurred after 9 wk of interference from a natural infestation of weeds, including redroot pigweed (Saghir and Markoullis 1974). In addition, when potatoes competed with 5 common lambsquarters (*Chenopodium album* L.) m^{-2} season-long, yield was decreased 43%, and 40 plants m^{-2} of scentless chamomile [*Tripleurospermum perforatum* (Mérat) Laínz] caused a 73% yield reduction (Everaarts and Satsyati 1978).

Wall and Friesen (1990) saw total and marketable tuber yields reduced by green foxtail [*Setaria viridis* (L.) Beauv.] densities of less than 75 plants m^{-2} competing season-long with potatoes. The critical quackgrass [*Elymus repens* (L.) Gould] interference period in potato depends on density and environment, and at high infestations, the critical period begins before potato emergence (Baziramakenga and Leroux 1994, 1998; Ivany 1981, 1986). Season-long interference of 150 quackgrass shoots m^{-2} is known to reduce potato yield by 78% (Ivany 1986). As the length of time before quackgrass removal increased in this study, potato yields decreased, and that for maximum potato yield to be achieved, quackgrass must be removed during the first 2 to 4 wk after crop emergence and potatoes kept weed-free for as long as 42 DAE. These researchers found that the beginning of quackgrass interference varies less than the end of it, indicating that quackgrass control before potato emergence is necessary to prevent yield loss. However, Baziramakenga and Leroux (1994) also noted that preventing late interference can reduce tuber perforation by quackgrass rhizomes as well as facilitate harvest.

Potato cultivar differences, especially in canopy growth characteristics, can impact competitiveness of potato (Conley et al. 2001; Connell et al. 1999; Nelson and Thoreson 1981, Selleck and Dallyn

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1978; Sweet et al. 1974; Yip et al. 1974). Sweet et al. (1974) found that cultivars which intercepted the most light were found to better suppress weeds. Small-statured 'Red Pontiac' and large-vined 'Dark Red Norland' yields were reduced 45 and 65%, respectively, when grown in season-long weedy conditions with wild oat (*Avena fatua* L.), redroot pigweed, and foxtail (*Setaria* sp.), compared with weed-free controls (Nelson and Giles 1989). Hutchinson et al. (2011) found that tuber yield and quality of Russet Norkotah, an early-maturing cultivar with a relatively small, upright canopy and determinant growth (Love et al. 1995), was reduced when only 1 hairy nightshade plant m^{-1} row competed season-long. However, yield reduction did not occur with 'Russet Burbank', a late-maturing cultivar with a large, spreading canopy and indeterminant growth, until competing season-long with 2 hairy nightshade plants m^{-1} row.

An estimation of the critical period of weed interference would be useful in developing effective weed-control strategies (Singh et al. 1996), and in potatoes, where relatively noncompetitive cultivars are grown per market needs, these strategies might be specific to a given cultivar (Colquhoun et al. 2009). Hairy nightshade is problematic season-long in potatoes; however, previous research has not been conducted to find the time period when potatoes must be free of this weed. Therefore, the objective of this study was to determine the critical hairy nightshade interference period in Russet Norkotah, a low-competitive cultivar.

Materials and Methods

The hairy nightshade critical interference period field study was conducted in 2006 and 2007 in Idaho at the Aberdeen Research and Extension Center on a Declo loam (coarse-loamy, mixed, mesic, Xerollic Calciorthid) with 1.2 to 1.4% organic matter and pH 7.9 to 8.1. Russet Norkotah seed pieces were planted May 3, 2006 and May 3, 2007 in plots three rows wide by 12 m long. In- and between-row spacing both years was 25 and 91 cm, respectively. When emergence of full-leaf potato plants in the plots was greater than 75% (on June 1 both years), one- to two-leaf hairy nightshade plants which had been germinated and grown in the greenhouse in Jiffy-Pots (Jiffy Product Ltd., 125 Parc Industrial St., Shippagan, New Brunswick E8S1X9, Canada) were transplanted at a 2 plant m^{-1} row density in the furrow between potato rows and allowed to grow for 10, 20, 30, or 40 d after the time of transplanting at potato emergence before removal. In other treatments, the potatoes were maintained weed-free for 0, 10, 20, 30, or 40 d after potato emergence (DAE) before transplanting. Each year, treatments were arranged in a randomized complete block resign with six replications. Potatoes were harvested from the center row of each plot at the end of the growing season (October 3, 2006 and September 24, 2007), and yield and grade according to USDA standards (USDA–AMS 2008) was determined. Hairy nightshade biomass was collected as weeds were removed according to treatment or prior to potato harvest from randomly selected 0.25 m^2 quadrats on each side of the center row of each plot. The subsamples were combined and placed in a dryer at 70 C for 1 wk, after which biomass was calculated on a dry-weight basis. In 2007, hairy nightshade berries in each subsample were counted.

Each year, the experimental area was fertilized according to university recommendations before planting and received standard irrigation to maintain a minimum soil-water content of 65% field capacity during the growing season. Additional fertilizer was applied through the irrigation system throughout each growing season based on periodic petiole analysis. Trial areas were kept free of all weeds except the designated hairy nightshade treatments by periodic hand-weeding.

Data Analyses. An ANOVA was performed using PROC GLM in SAS (Version 9.2, SAS Institute, Cary, NC 27513). Biomass and yield data were subjected to regression analysis and fit to linear and nonlinear models using PROC GLM and PROC NLIN. There were no year by treatment interactions for hairy nightshade or potato results, so data were combined over years.

Results and Discussion

Hairy Nightshade Biomass. Even though Russet Norkotah does not have an upright canopy, hairy nightshade growth each year did not extend above the potato foliage during the growing season (general observation); however, hairy nightshade with spreading growth are common (Ogg et al. 1981) and that is what was observed in this trial. Hairy nightshade dry weight exhibited a quadratic

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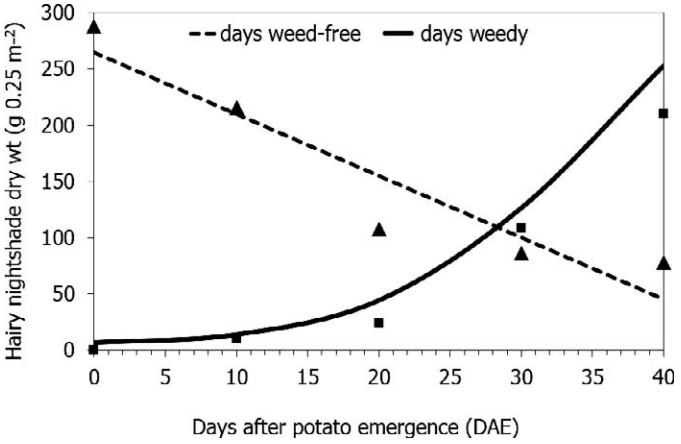


Figure 1. Effect on hairy nightshade dry weight of transplanting at a 2 m^{-1} row density and allowing them to grow for 10, 20, 30, or 40 d after emergence of potatoes (DAE) before removal or maintaining the potatoes weed-free for 0, 10, 20, 30, or 40 DAE before transplanting. Days weed-free response followed a linear model where $y = 594.31 + (-54.94 * x)$ and R^2 was 0.88 Days weedy relationship was quadratic where $y = 65.14 + (-74.14 * x) + (22.35 * x^2)$ and R^2 was 0.87.

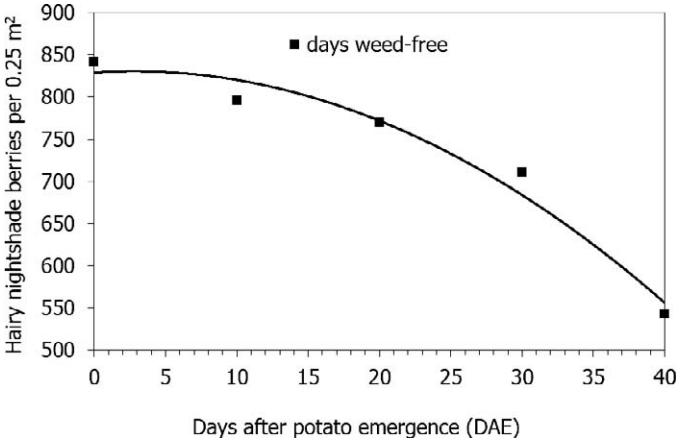


Figure 2. Number of hairy nightshade berries when greenhouse-grown hairy nightshade were transplanted at 2 m^{-1} row density 0, 10, 20, 30, or 40 d after emergence (DAE) of Russet Norkotah potatoes and allowed to grow until potato harvest at end of growing season. The relationship was quadratic and the equation was $y = -783.5 + (444.52 * x) + (-30.92 * x^2)$ with an R^2 of 0.42.

response when graphed according to removal 10, 20, 30, and 40 d after transplanting at potato emergence and including the weed-free control, ranging from 0 to 210.4 g 0.25 m^{-2} (Figure 1). This increase in dry weight at the time before removal was quadratic. When transplanting occurred at 0 DAE (weedy the entire season), or at 10, 20, 30, or 40 DAE, dry weight decreased in a linear manner from 287.7 to 77.7 g 0.25 m^{-2} (Figure 1). Berries produced by the plants in the sampling area were counted, and if hairy nightshade were transplanted at potato emergence and not removed until potato harvest, berry numbers reached 841.7 per 0.25 m^2 (Figure 2). As the interval from potato emergence to transplant time increased from 10, 20, 30, to 40 d, the number of berries produced in the sample area decreased from 770, 795, 711, to 543 per 0.25 m^2, respectively. The relationship between transplant time and berry number was quadratic, and as time before transplanting increased, berry number decreased. No berries were found on hairy nightshade planted at potato emergence then removed 10 or 20 d later; however, if the plants were allowed to grow for 30 and 40 DAE, then 30 and 75 berries, respectively, were collected from the sampling areas (data not shown).

Connell et al. (1999) reported that 96% or greater shading by potato is necessary for general weed control. As mentioned, Russet Norkotah, the variety used in our study, has a relatively small, upright canopy and determinant growth. In Idaho's short growing season of 115 frost-free d or less (Love et al. 2009) where this study was conducted, Russet Norkotah foliage might not even close over the rows to completely shade below-canopy ground. For instance, in trials conducted 2004 and 2005 with Russet Norkotah in Idaho (Hutchinson et al. 2011), maximum shading by Russet Norkotah occurred 6 wk after emergence (WAE) and was 21 and 61%, respectively, after which natural senescence began and shading decreased dramatically. Averaged across season-long hairy nightshade densities in that trial ranging from 1 to 3 m^{-1} row, or 100 m^{-2}, the number of hairy nightshade berries m^{-2} was 4,160. In the current study, the calculated number of berries m^{-2} was 3,367 when hairy nightshade at a density of 2 plants m^{-1} row were allowed to grow from potato emergence until the end of the growing season (data not shown).

Russet Norkotah Tuber Yields. If hairy nightshade were present from potato emergence until harvest at the end of the growing season approximately 3 mo later, U.S. No. 1 (tubers weighing at least 113 g and with no defects) yield was reduced 31% compared with weed-free yield (Figure 3). Total tuber yield was reduced to 77% of the weed-free check yield when hairy nightshade was present throughout the

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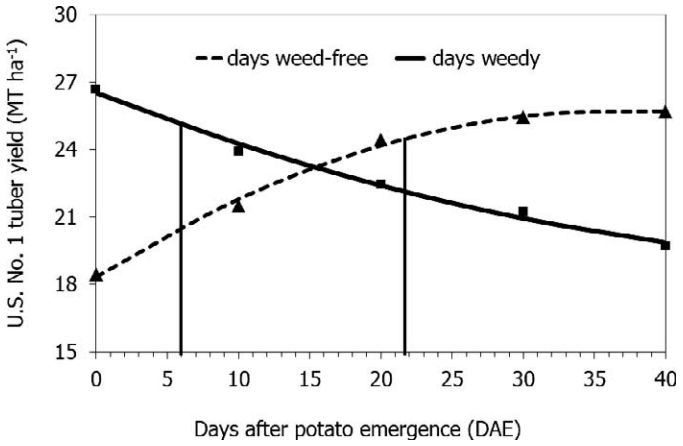


Figure 3. Effect on Russet Norkotah U.S. No. 1 tuber yields (tubers weighing at least 113 and with no defects) of transplanting hairy nightshade at a 2 m^{-1} row density and allowing them to grow for 0, 10, 20, 30, or 40 d after emergence of potatoes (DAE) before removal or maintaining the potatoes weed-free for 0, 10, 20, 30, or 40 DAE before transplanting. The relationship was quadratic for both days weed-free and days weedy. The equation for days weed-free was $y = -24.975 + (10.44 * x) + (-0.54 * x^2)$ and R^2 was 0.84. The equation for days weedy was $= 29.18 + (-2.86 * x) + (0.2 * x^2)$ and R^2 was 0.69. The vertical solid lines represent critical time of removal or time kept weed-free needed before a 5% yield reductions occured. Symbols mark the actual data points.

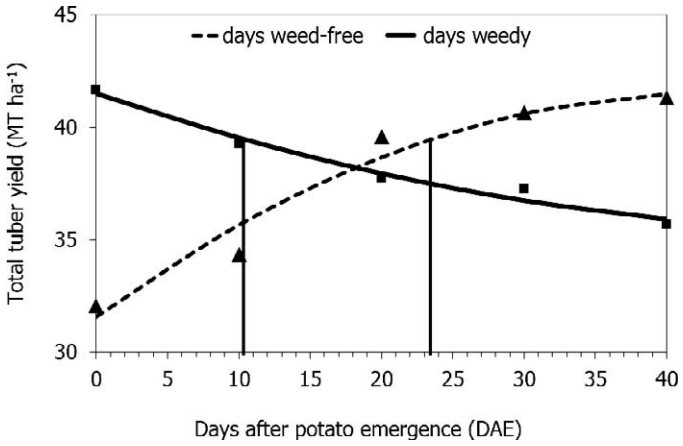


Figure 4. Effect on Russet Norkotah total tuber yields of transplanting hairy nightshade at a 2 m^{-1} row density and allowing them to grow for 0, 10, 20, 30, or 40 d after emergence of potatoes (DAE) before removal or maintaining the potatoes weed-free for 0, 10, 20, 30, or 40 DAE before transplanting. The relationship was quadratic for both days weed-free and days weedy. The equation for days weed-free was $y = -15.29 + (11.01 * x) + (-0.53 * x^2)$ and R^2 was 0.70. The equation for days weedy was $= 43.82 + (-2.53 * x) + (019 * x^2)$ and R^2 was 0.31. The vertical solid lines represent critical time of removal or time kept weed-free needed before a 5% yield reductions occured. Symbols mark the actual data points.

growing season (Figure 4). As mentioned previously, Hutchinson et al. (2011) found that Russet Norktoah U.S. No. 1 and total tuber yields were reduced when only 1 hairy nightshade plant m^{-1} row competed season-long. In that study U.S. No 1 yield was reduced 21, 26, 27, or 48% by densities of 1, 2, 3 or 100 hairy nightshade m^{-1} row, respectively, compared with weed-free U.S. No. 1 yields. Total tuber yield reductions ranged from 16 to 37% from those same weed densities in that study. Similarly, a natural, mixed stand of annual weeds caused a 54% yield reduction when emerging before potatoes and competing season-long (Nelson and Thoreson 1981).

When hairy nightshade were transplanted at potato emergence in the current study and removed 10, 20, 30, or 40 DAE, U.S. No. 1 and total tuber yields decreased quadratically as this weedy period increased (Figures 3 and 4). When hairy nightshade were transplanted at 0 DAE (weedy the entire season), or transplanting did not occur until 10, 20, 30, or 40 DAE, tuber yields increased in a quadratic manner as this weed-free period increased (Figures 3 and 4). U.S. No. 1 tuber yield ranged from 18.5 to 26.7 MT ha^{-1}. Russet Norkotah U.S. No. 1 yield was similar to weed-free yield when transplanting was delayed up to 22 DAE (Figure 3). Yield was reduced by 5% or more if hairy nightshade was allowed to remain after 6 DAE. The vertical bars on the graph represent the point in time when the 5% yield loss occurs for weed-free and weedy treatments. The choice of a given crop loss percentage to determine the critical weed interference is somewhat arbitrary and the range of percent yield loss can vary by the risk that growers are willing to take (Knezevic et al. 2002). We chose 5% because even in a conservative potato market, this amount of yield reduction can represent a loss of \$41 ha^{-1} (Hutchinson et al. 2007) to even \$195 ha^{-1} (Liebman et al. 1996).

Total tuber yields ranged from 32.1 to 41. 6 MT ha^{-1}, and a 5% loss occurred when weedy and weed-free periods were 10 and 24 DAE, respectively (Figure 4). Therefore, the period Russet Norkotah must remain free of hairy nightshade or else U.S. No. 1 and total tuber yields losses of 5% or greater will occur, are 6 to 22, and 11 to 24 DAE, respectively. The critical weed-free period most likely begins earlier for U.S. No. 1, than for total

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tuber yields because more time is needed for tubers to develop to the size requirement for U.S. No. 1 grade category of at least 113 g. Similar to what occurred in the current study where the weed-free period needed to be 24 DAE, Nelson and Thoreson (1981) saw a 16% tuber yield reduction when annual weeds emerged 3 wk after potatoes and were allowed to grow season-long. In contrast, however, Vitolo and Ilnicki (1985) found that natural stands of grasses can compete with potatoes for 6 to 8 wk before potato yield is reduced and that a 2- to 4-wk weed-free period is sufficient for maximum potato yield. Another study revealed that the critical weed-free period lasted from planting to 13 wk later if weeds such as common chickweed [*Stellaria media* (L.) Vill.] and common lambsquarters were present (Ciuberkis et al. 2007). Other researchers have found that a 4- to 6- or 7-wk weed-free period was required for optimum potato tuber yield (Connell et al 1999; Singh 2003; Thakral et al. 1989) or that the critical period of weed interference is from 3 to 5 wk after potato emergence (Lazauskas and Razukas 2001).

Potato varieties that emerge quickly, exhibit rapid early growth, and have an upright dense canopy, are not impacted as much by weed interference as are other varieties (Sweet and Sieczka 1973; Webb et al. 1978). Long-season potato varieties generally are also more competitive than early-season varieties (Connell et al. 1999; Selleck and Dallyn 1978). In a Wisconsin trial comparing competitiveness of 10 potato cultivars, the ones that emerged and developed a full canopy slowly, compared with others in the study, suffered yield losses when weeds competed season-long, or even when kept weed-free from 0 to 4 WAE then left weedy until harvest (Colquhoun et al. 2009). In contrast, if the relatively noncompetitive Russet Norkotah in the current study was kept free of hairy nightshade for 24 d after potato emergence, yield loss was only 0 to 5%. This difference was probably because the dominant weed species in the Wisconsin trial were common lambsquarters, redroot pigweed, green foxtail, and common ragweed (*Ambrosia artemisiifolia* L.). In addition, the Wisconsin study weed density exceeded the 2 hairy nightshade m^{-1} row in the current study and most likely grew further above the potato canopy than hairy nightshade to compete for light as well as nutrients and water.

We originally hypothesized that because Russet Norkotah does not compete as well against hairy nightshade as larger-canopied varieties such as Russet Burbank, the critical interference period for this weed in Russet Norkotah would last longer than 24 DAE. However, the potato vegetative stage of vigorous growth begins approximately 54 d after planting (DAP) (Sharifi et al. 2005), which in Idaho correlates to about 3 WAE and the end of the necessary weed-free period required for $< 5\%$ yield loss in our study. Vigorous potato growth at this time would translate to the beginning of competitiveness against weeds. Also at that time, Russet Norkotah roots are the densest at the 0- to 15-cm depth of the potato hill and shoulder positions (Sharifi et al. 2005). Peachy and Mallory-Smith (2007) found the optimal hairy nightshade seed emergence occurred from a 12 cm depth in soil, and others determined that maximum emergence of this weed occurs at about 2 cm below the surface and decreases to zero at a depth of approximately 8 cm (Zhou et al. 2005). Either way, hairy nightshade germination is within the zone of Russet Norkotah, rooting and competing with the potato for nutrient/water uptake.

Because the critical hairy nightshade weed interference period for Russet Norkotah is from 6 to 24 DAE, control of this weed should occur during this period to prevent a 5% or greater loss. Postemergence rimsulfuron could be used as long as the hairy nightshade were small and had not been present for longer than 6 DAE. Rimsulfuron labels state that hairy nightshade must be $\leq$ 1 inch tall for satisfactory POST control (Hutchinson et al. 2005a). However, we found that even if hairy nightshade presence did not occur until 40 DAE, the plants could produce as many as 2,100 berries per m^2. At an average of 11 seeds per berry (Hutchinson et al. 2011), over 23,000 hairy nightshade seeds could be added to the weed seedbank in a single season. These seeds could begin to germinate as soon as the following spring, with some remaining viable for as long as 10 yr (Ogg and Rogers 1989). Potato is generally grown in a 3- or 4-yr rotation in the PNW, so if hairy nightshade is not controlled adequately in a given potato planting year and viable seed production occurs, then many of those seeds could be present to germinate and

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compete the next time potatoes are planted in the rotation.

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