The Effect of Weed-free Period and Nitrogen on Eastern Black Nightshade Competition with English Pea

Michael P. Croster¹ and John B. Masiunas²

Department of Natural Resources and Environmental Sciences, University of Illinois, 1201 West Gregory Drive, Urbana, IL 61801

Additional index words. critical weed-free period, crop contamination, fertility, interference, *Pisum sativum*, replacement series, *Solanum ptycanthum*

Abstract. Studies established the critical period for eastern black nightshade (nightshade) (*Solanum ptycanthum* Dun.) competition in pea (*Pisum sativum* L.) and determined the effect of N fertility on pea and nightshade growth. In 1992, pea yields were most affected when nightshade was established at planting and remained for 4 or 6 weeks, while in 1993, competition for 6 weeks caused the greatest reduction in pea yields. In a sand culture study, pea biomass and N content were not affected by three N levels (2.1, 21, and 210 mg·L⁻¹). Nightshade plants were five to six times larger in the highest N treatment than at lower N levels. Nitrogen content of nightshade was 0.76% at 2.1 ppm N and 3.22% at 210 ppm N. Choosing soils with low N levels or reducing the N rates used in pea may decrease nightshade interference and berry contamination of pea.

Eastern black nightshade (nightshade) is a severe problem in processing peas grown in the midwestern United States. Nightshade interference in pea increases production costs and results in contamination problems. Immature berries are similar to peas in color and size (Gane, 1985). Mature nightshade berries often rupture during harvesting, causing seeds and soil particles to cling to the harvested crop (McGiffen and Masiunas, 1992). The critical weed-free period and the competitiveness of nightshade with pea are not known. If the critical weed-free period could be established, growers could better target nightshade control and decide if cultivation or postemergence herbicides are necessary to maintain pea yield.

Nightshade germinates at soil temperatures above 17 °C, emerges through July, and can produce viable seed within 6 weeks after germination (Keeley and Thullen, 1983; Nelson and Nylund, 1962; Roberts and Locket, 1978; Thomson and Witt, 1987), making nightshade control important in both early (spring) and late (summer) season crops of pea. Nightshade can grow in low-light intensities under a crop canopy (Stoller and Myers, 1989a).

Gaps in the pea canopy allow light penetration, resulting in prolific growth and seed production of nightshade.

Pea production systems contribute to nightshade problems. The herbicides metolachlor [2-chloro-*N*-(ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl) acetamide] and imazethapyr {2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1-*H*-imidazol-2-yl]-5-ethyl-3-pyridinecarboxylic acid} are registered for pea and will control nightshade, but they are not widely used because both chemicals can injure pea and can persist in the soil to damage subsequent crops. Nightshade growth is favored by irrigation, disturbed habitats, and high N levels (Rogers and Ogg, 1981; Weller and Phipps, 1978), all common factors in pea production areas in the midwestern United States. Current recommendations are to apply N at 82 kg·ha⁻¹ to pea (Illinois Cooperative Extension Service, 1996). Pea–nightshade competition may be shifted to favor pea by manipulating field N levels.

No studies on the effects of N fertility on nightshade competition with pea are known to the authors. Pea fixes atmospheric N, making it less responsive to N fertilizers than are other vegetable crops (Swiader et al., 1993). In an intercrop of pea, barley (*Hordeum vulgare* L.), and mustard (*Brassica rapa* L.), increasing N benefited mustard much more than it did pea (Liebman, 1989; Liebman and Robichaux, 1990). Nitrogen application did not affect pea, but more than doubled the size of mayweed chamomile (*Anthemis cotula* L.) (Ogg et al., 1994). Jensen (1986a, 1986b) reported that N at 50 kg·ha⁻¹ did not increase seed yield or the N content of pea compared to a nonfertilized control. A reduction in recommended N rates might reduce nightshade growth and berry production without affecting pea yield.

Our objectives were to establish the critical weed-free period for controlling eastern black nightshade in pea and to determine the effects

of N fertility on competition of nightshade with pea.

Materials and Methods

Experiment 1. Critical weed-free period. Studies were conducted at the Univ. of Illinois Vegetable Research Farm in Champaign. The soil type was a Flanagan silt loam (fine montmorillonitic, mesic, Aquic Argiudoll) with 4% to 5% organic matter. Treatments were: nightshade control all season long (no weeds); season-long nightshade competition (weedy); nightshade competition for 2 or 4 weeks after pea planting (WAP) with no nightshade the remainder of the growing season; and nightshade planted into the crop at 2 or 4 weeks with nightshade competition for the remainder of the growing season. A randomized complete-block design was employed, with four replications using plots 2.7 × 5.4 m.

Trifluralin [2,6-dinitro-*N,N*-dipropyl-4-(trifluoromethyl)benzenamine] herbicide at 0.5 kg·ha⁻¹ was preplant-incorporated to control weeds other than eastern black nightshade. Emerged broadleaf weeds other than eastern black nightshade were controlled by hand-weeding and, in 1993, by an additional postemergence application of bentazon [3-(1-methylethyl)-(1*H*)-2,1,3-benzothiadiazin-4(3*H*)-one 2,2-dioxide] at 1.1 kg·ha⁻¹ with 0.25% crop oil (v/v). 'Spring' pea seed, not inoculated with *Rhizobium leguminosarum*, was drilled at ≈170 kg·ha⁻¹ with an 18-cm spacing between rows on 29 May and 31 July 1992 and 27 May 1993. A high seeding rate was used to assure a good crop stand. Two to 3 cm of water was applied per week from either rainfall or irrigation.

Nightshade transplants with five true leaves (≈5 weeks old) were established at five plants/m² within 2 d after seeding pea. Previous studies with soybean and tomato have indicated that nightshade at five plants/m² can significantly reduce crop yield (McGiffen et al., 1992; Stoller and Myers, 1989a, 1989b). Transplants of eastern black nightshade were used because of difficulties in getting uniform nightshade germination and to allow us to establish exact densities of nightshade throughout the growing season. Transplants are also planted at a more uniform depth than endemic populations, a factor important in vigor. Other researchers have also used nightshade transplants (McGiffen et al., 1992; Perez and Masiunas, 1990).

Nightshade fresh and dry mass were measured every 2 weeks. Degree-days were calculated using air temperatures from the Champaign, Ill., weather station, which is within 1 km of the experimental site. The base temperature used for *S. ptycanthum* was 6 °C (Alm et al. 1988). The rate of biomass increase for eastern black nightshade was modeled using the following equation (McGiffen and Masiunas, 1992).

$$\text{Mass} = a[e^{b(\text{degree-days})}] \quad [1]$$

The "a" parameter represents the x-intercept term and serves as an estimate of nightshade

Received for publication 9 June 1997. Accepted for publication 30 July 1997. We thank John Swiader for the use of his laboratory to conduct the nitrogen analysis, Elizabeth Wahle and Harry Bottenberg for assistance with the statistical analysis, and Asgrow Seeds for donating the pea seed. This research was supported in part by the Illinois Pesticide Impact Assessment Program. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

¹Former Graduate Research Assistant. Current address: Dept. of Agronomy, Univ. of Kentucky, Lexington, KY 40546.

²Associate Professor; to whom reprint requests should be addressed.

mass at emergence. The "b" parameter represents the slope of the regression and estimates the rate of nightshade growth.

A 0.6-m² sample of pea was harvested 6 weeks after planting from the center of each plot on 7 July and 13 Sept. 1992 and 6 July 1993. The pea was shelled and the seed was weighed and counted. Yield data were grouped two ways for analysis (Perez and Masiunas, 1990). Data from plots with eastern black nightshade established at pea planting and removed at 2, 4, or 6 WAP determined the maximum period of nightshade competition after crop planting that did not reduce yield. Data from plots with nightshade transplanted at 0, 2, and 4 WAP and remaining until pea harvest determined the minimum weed-free period after planting needed for maximum pea yield. Data were analyzed using analysis of variance and, if length of competition significantly affected pea yield, then regression was performed. Inverse, logarithm, cubic, quadratic, and linear terms were evaluated in the regression equations.

Experiment 2. Replacement series. 'Spring' pea was seeded and bareroot eastern black nightshade plants with four true leaves were transplanted into 38-L pots containing sterilized silica quartz sand. There were a total of eight plants per pot. The plants were spaced on a 5-cm grid. The proportions were either 0:8, 2:6, 4:4, 6:2, or 8:0 pea to nightshade. Greenhouse set-point temperatures were 23 °C day/20 °C night. Pea seeds were not inoculated in the first study; in the second, they were inoculated with *Rhizobium leguminosarum* Baldwin et Fred. at 0.6 g inoculum per kilogram of seed.

Hoagland's solution #2 (Hoagland and Arnon, 1950) was modified to provide N at 2.1, 21, and 210 mg·L⁻¹ with other essential nutrients constant (Table 1). The highest concentration is the standard Hoagland's solution. Rates of N at 2.1 and 21 mg·L⁻¹ were chosen to represent low N and an average rate of soil N for a sandy soil, respectively (Swiader et al., 1993). Nutrient solution (500 mL) was applied to each pot three times a week in an open hydroponic system. A trickle irrigation system supplied 500 mL of additional water twice a week. Once a week, after one of the waterings, the pots were leached with an additional 1 L of water to eliminate salt buildup.

On 17 Mar. and 2 Oct. 1993 (≈10 WAP), when both pea and nightshade had mature fruit, plants were individually harvested from each pot. Fruits were removed from the shoots and the peas shelled. The fresh masses of shoots and fruit were determined and the

number of pea seeds and nightshade berries counted. Plants were weighed after drying for 2 d at 60 °C.

One hundred milligrams of pea or nightshade dried shoots and fruits were ground to a fine powder with a Wiley Mill equipped with a no. 40 mesh screen. A modified Kjeldahl digestion and colorimetric assay developed by Cataldo et al. (1974) was used to determine total N. Absorbance was read at 625 nm and compared with a standard curve to determine total N. Total plant N was expressed on a percent dry-mass basis.

The experimental design was a randomized complete block with three replications. There was no significant trial or N level by proportion (pea × nightshade) interactions; therefore, both trials were combined for analysis and only main effects were analyzed using regression analysis. Inverse, logarithm, cubic, quadratic, and linear terms were evaluated in regression equations.

From the dry mass per plant, plant relative yield (PRY) was calculated using the method of de Wit (1960).

$$PRY_{ij} = (Y_{ij}/Y_i) \quad [2]$$

and

$$PRY_{ji} = (Y_{ji}/Y_j) \quad [3]$$

The PRY of pea (i) in mixture with nightshade (j) is the yield (biomass per plant) of pea in a mixture divided by the yield (biomass per plant) of pea in a monoculture. A PRY_{ij} (or PRY_{ji}) of 1.0 means that pea (or nightshade) yields equally well in mixture and monoculture. A PRY_{ij} (or PRY_{ji}) > 1.0 implies that pea (or nightshade) experiences less competition from nightshade (or pea) than it does with individuals of its own species; PRY_{ij} or PRY_{ji} < 1.0 implies the reverse; thus, the species yields less in mixture than in monoculture.

The relative productivity per unit area for a particular proportion of pea and nightshade growing in competition can be predicted by calculating the relative yield total (RYT). Let *p* = proportion of pea in the mixture and *q* = proportion of eastern black nightshade in the mixture; so that *p* + *q* = 1. The density was constant with eight plants per pot, then:

$$RYT_{ij} = pPRY_{ij} + qPRY_{ji} \quad [4]$$

The RYT is the weighted average of the plant relative yields of the mixture compo-

nents (de Wit, 1960). RYT values of 1.0 indicate that the nightshade and pea are competing for the same resource, i.e., they are potentially mutually exclusive. Values >1.0 suggest avoidance of competition, whereas a RYT <1.0 indicates mutual antagonism (Snyder et al., 1996).

Results and Discussion

Experiment 1. Critical weed-free period.

There were greater differences between treatments in 1993 vs. 1992, probably due to variations in weather conditions. In 1992, the weather during May and June was cool, averaging 16.1 and 20.6 °C, respectively, compared with a 30-year average of 17.1 and 22.3 °C, respectively. In 1993, the temperatures averaged 1 °C warmer. Rainfall in July (33.1 and 20.7 cm in 1992 and 1993, respectively) was above the 30-year average of 11.4 cm. Although variation in rainfall between years explained the differences in pea yields in other competition studies (Nelson and Nylund, 1962; Wall et al., 1991), the heavy rainfall in July plus our supplemental irrigation should have provided sufficient moisture. Nightshade has a higher optimum temperature for growth than pea; thus, the warmer temperatures in May and June 1993 might have promoted the growth of nightshade more than that of pea, thereby increasing nightshade competitiveness.

The pea yields were similar in the Spring and Fall 1992 trials, so the data were combined for analysis. Pea mass in both years was highest in the no-weed treatment and lowest in the 4 WAP (1992) or 6 WAP (1993) treatments (Table 2). Time of establishment of nightshade affected pea yield. For example, in 1992, pea yields were reduced more when nightshade was present from pea emergence through 4 WAP than when present from 2 WAP until pea harvest. In 1992, pea yields in plots with season-long competition were greater than when nightshade was removed 2 weeks before harvest, probably because removal injured the pea plants.

In 1993, yields of pea were lower when nightshade was present at harvest than when the weed was removed before harvest. Nightshade planted when the pea was seeded and allowed to grow for up to 4 weeks did not reduce crop yield, whereas season-long nightshade competition dramatically decreased yield. Nightshade planted at week 4 and re-

Table 1. Nutrient solutions used for Expt 2.

Salt	N concn (mg·L ⁻¹)		
	2.1	21	210 ^z
	<i>Salt concn (mg·L⁻¹)</i>		
NH ₄ H ₂ PO ₄	0	115	115
KNO ₃	15	54	606
MgSO ₄	485	485	485
CaCl ₂	588	588	15
Ca(NO ₃) ₂	0	0	941
K ₂ SO ₄	357	479	0
K ₂ H ₂ PO ₄	136	0	0

^zStandard Hoagland's solution #2.

Table 2. The effect of period of time of competition by eastern black nightshade on pea yield.^z Plants were harvested 6 weeks after planting. Expt. 1.

Eastern black nightshade		Shelled pea mass		No. shelled peas	
Establishment	Removal	(Mg·ha ⁻¹)		(millions/ha)	
(week)	(week)	1992 ^y	1993	1992 ^y	1993
0	0 (no weeds)	4.57 a ^x	4.80 a	11.6 a	12.7 a
0	2	3.00 cd	4.20 a	7.93 bc	11.0 a
0	4	2.78 d	4.05 a	7.38 c	12.2 a
0	6	3.54 bc	1.90 c	9.70 ab	5.20 c
2	6	3.73 b	2.82 b	9.82 ab	8.10 b
4	6	4.05 ab	2.70 bc	10.1 a	8.20 b

^zNone of the one-, two-, or three-factor models using the inverse, logarithm, linear, quadratic, or cubic terms for week were significant.

^yThe two 1992 experiments were combined.

^xMean separation within columns by LSD, *P* < 0.05.

maining to harvest (2 weeks of competition) reduced crop yield. Warm temperatures, averaging 23.9 °C between weeks 4 and 6, may have promoted nightshade growth just before crop harvest, reducing pea yield.

In the 1993 trials, the lack of a yield effect from nightshade planted with pea and removed at week 2 or 4 differed from the results of Nelson and Nylund (1962), who reported that pea growth and yield was most affected when white mustard (*Brassica hirta* Moench) was present at pea emergence. In 1992, when temperatures favored pea growth and nightshade was established after pea, crop yields were only reduced after 4 weeks of competition, while in 1993, pea yields were reduced after as little as 2 weeks of competition. This is less than the 8 weeks needed for white mustard competition to reduce pea yields (Nelson and Nylund, 1962). The difference in response may reflect the short-season pea cultivar we used, the differences in weed species and es-

tablishment method, or differences in environmental conditions. Nightshade remaining at harvest may have reduced yields in 1993 by interfering with hand-harvesting. We conclude that for best pea yields, nightshade must be controlled during the first 2 weeks of the growing season and later emerging nightshade must be eliminated before crop harvest.

In 1993, nightshade entered its exponential phase of growth after ≈500 degree-days or 5 WAP (Fig. 1). Between weeks 4 and 6, its dry mass increased from 5.5 to 85 g/plant and mature berries were produced. The higher temperatures during the 2 weeks before pea harvest facilitated nightshade growth, while lower temperatures earlier in the season slowed its growth. This implies that nightshade competition and contamination problems in pea will increase as temperatures rise. McGiffen and Masiunas (1992) reported that eastern black nightshade entered its exponential growth phase at ≈900 degree-days. The difference

between the two studies is probably the result of competition between nightshade and pea for light in our study. Stoller and Myers (1989a) also reported that shading by soybeans reduced nightshade growth.

Experiment 2. Replacement series. Pea shoot biomass, pod production, and proportion of biomass in the pod and seed were not affected by N fertility rate or the proportion of pea in the mixture (Table 3). An increase in the proportion of pea mass contained in the seeds is a common response to competition (Gane, 1985; Lawson, 1982). Although pea was inoculated with *R. leguminosarum* in trial 2, there were no differences in pea biomass between trials, and no nodulation of pea roots was found in either trial. The sand culture may have inhibited nodulation or the inoculum may have been leached from the pots.

Nightshade shoot dry mass per plant was largest when there were two nightshade and six pea plants in the mixture (Table 3). The larger nightshade plants could be caused by their being better able to obtain resources when competing against pea than when competing against themselves. Nightshade fruit mass and total mass were less in the monoculture and the 4 pea : 4 nightshade mixture. The lower nightshade biomass in the monoculture is consistent with nightshade being more affected by intraspecific than interspecific competition.

Values for PRY were averaged across fertility levels because the interaction between the proportion of a species per pot and N rate was nonsignificant. In the 6 pea : 2 nightshade mixture, the PRY values were <1.0, indicating that interspecific competition was more intense than intraspecific competition (Table 4). Thus, the two species grew less in the mixture than in monoculture. In the other two mixtures, the PRY values for pea were ≈1.0, meaning that pea competes equally well in mixture and in monoculture (Snyder et al., 1994). In the 4 pea : 4 nightshade mixture, the PRY was >1.0, indicating that nightshade experienced less interspecific than intraspecific competition. Since pea was probably not fixing atmospheric N and the N fertility × proportion interaction was nonsignificant, PRY values >1.0 were not due to improved N availability for nightshade growing with pea. A more probable explanation was that the smaller pea shoots allowed nightshade shoots to capture more light.

Fig. 1. The increase in eastern black nightshade dry mass as a function of degree-days. The equation is Nightshade mass = $0.1123[e^{0.01014(\text{degree-days})}]$, $r^2 = 0.96$. Expt. 1.

Table 3. The effect of differing proportions of pea to nightshade plants on shoot and fruit biomass (g/plant). Expt. 2.

Proportion (no./pot)		Pea mass ^z						Nightshade mass ^z					
Pea	Nightshade	Shoot ^y		Fruit ^x		Total		Shoot ^y		Fruit ^x		Total	
		Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
8	0	3.65 ^w	0.74	4.78	0.65	8.43	1.39	---	---	---	---	---	---
6	2	3.24	0.64	3.90	0.54	7.14	1.18	5.08 a ^v	0.90 ab	4.69 a	0.78 a	9.77 a	1.68 ab
4	4	3.58	0.71	4.84	0.58	8.42	1.29	3.89 bc	0.81 b	3.77 b	0.63 b	7.66 b	1.44 bc
2	6	3.10	0.79	4.71	0.53	7.81	1.32	4.19 b	1.15 a	4.90 a	0.82 a	9.09 a	1.97 a
0	8	---	---	---	---	---	---	3.18 c	0.54 c	3.63 b	0.65 b	6.81 b	1.19 c

^zAverages for both trials.

^yTotal for stems and leaves.

^xTotal mass of pods and seeds for pea and of berries for nightshade.

^wNo significant effect on pea fresh or dry mass by analysis of variance.

^vMean separation within columns by LSD, $P < 0.05$.

Table 4. The plant relative yields and relative yield totals of competing pea and nightshade grown in pots. Values are averaged over N rates. Expt. 2.

Proportion		Plant relative yields (PRY)		Relative yield totals (RYT)
Pea	Nightshade	Pea w/nightshade	Nightshade w/pea	
6	2	0.85*	0.86*	0.85*
4	4	0.93 ^{NS}	1.17*	1.05 ^{NS}
2	6	0.95 ^{NS}	0.71**	0.77*

^{NS}, *, ** Not significantly different or significantly different from 1.0 at $P < 0.05$ or 0.01 , respectively. PRYs and RYT were compared with 1.0 (yield in monoculture or sum of expected yields for both species in mixture, respectively) using the t test.

The RYT varied depending on the proportion of pea and nightshade growing in competition (Table 4). In the 4 pea : 4 nightshade mixture, the RYT value was ≈ 1.0 , indicating that the nightshade and pea were competing for the same resources. In the other mixtures, the RYT was < 1.0 , indicating mutual antagonism (Snyder et al., 1996).

Pea growth and N content were not affected by N application rate (data not shown). The lack of an effect could be due to low pea N requirements or efficient uptake and utilization of N by pea. Pea has low N requirements compared with other crops (Illinois Cooperative Extension Service, 1996; Swiader et al., 1993). Increasing N rates improves growth of competing plants more than that of pea (Liebman, 1989; Liebman and Robichaux, 1990; Ogg et al., 1994). In contrast, N rates affected nightshade growth N concentration; the N content of the plants was 0.76% at 2.1 mg·L⁻¹ and 3.22% at 210 mg·L⁻¹. At 2.1 and 21 mg·L⁻¹, vegetative growth and fruit production were lower than at 210 mg·L⁻¹ and foliar chlorosis was evident. Nightshade may be less efficient at N uptake and usage or have higher N requirements than pea.

The difference in response to N combined with our findings on the critical period for nightshade control could be exploited to reduce nightshade problems in pea production. We recommend further research to determine if nightshade competition with pea is reduced in fields that are low in soil N and if N fertility programs for pea could be designed to reduce applied N. These changes, along with controlling nightshade for the first 2 weeks of pea growth and eliminating nightshade before pea harvest, may reduce nightshade competition and berry contamination of pea.

Literature Cited

- Alm, D.M., D.R. Pike, J.D. Hesketh, and E.W. Stoller. 1988. Leaf area development in some crop and weed species. *Biotronics* 17:29-39.
- Cataldo, D.A., L.E. Schrader, and V.L. Young. 1974. Analysis by digestion and colorimetric assay of total nitrogen in plant tissue high in nitrate. *Crop Sci.* 14:854-856.
- de Wit, C.T. 1960. On competition. *Versl Landbouwkond Onderz* 66:1-82.
- Gane, A.J. 1985. The pea crop—Agricultural progress, past, present and future, p. 3-15. In: P.D. Hebblethwaite, M.C. Heath, and T.C.K. Daweksins (eds.). *The pea crop—A basis for improvement*. Butterworths, London.
- Hoagland, D.R. and D.I. Arnon. 1950. The water-culture method for growing plants without soil. *California Agr. Expt. Sta. Circ.* 347.
- Illinois Cooperative Extension Service. 1996. Midwest vegetable production guide for commercial growers. *Circ.* C-1328. Univ. Illinois Coop. Ext. Serv., Urbana.
- Jensen, E.S. 1986a. The influence of rate and time of nitrate supply on nitrogen fixation and yield in pea (*Pisum sativum* L.). *Fert. Res.* 10:193-202.
- Jensen, E.S. 1986b. Symbiotic N₂ fixation in pea and field bean estimated by ¹⁵N fertilizer dilution in field experiments with barley as a reference crops. *Plant Soil* 92:3-13.
- Keeley, P.E. and R.J. Thullen. 1983. Influence of planting date on the growth of black nightshade (*Solanum nigrum* L.). *Weed Sci.* 31:180-184.
- Lawson H.M. 1982. Competition between annual weeds and vining peas grown at a range of population densities: Effect on the crop. *Weed Res.* 22:27-38.
- Liebman, M. 1989. Effects of nitrogen fertilizer, irrigation and crop genotype and canopy relations and yields of an intercrop/weed mixture. *Field Crops Res.* 22:83-100.
- Liebman, M. and R.H. Robichaux. 1990. Competition by barley and pea against mustard: Effects on resource acquisition, photosynthesis, and yield. *Agr. Ecosystems Environ.* 31:155-172.
- McGiffen, M.E., Jr. and J.B. Masiunas. 1992. Prediction of black and eastern black nightshade (*Solanum nigrum* and *S. ptycanthum*) growth using degree-days. *Weed Sci.* 40:86-89.
- McGiffen, M.E., Jr., J.B. Masiunas, and J.D. Hesketh. 1992. Competition for light between tomatoes and nightshades (*Solanum nigrum* or *S. ptycanthum*). *Weed Sci.* 40:220-226.
- Nelson, D.C. and R.E. Nyland. 1962. Competition between peas grown for processing and weeds. *Weeds* 10:224-229.
- Ogg, A.G., Jr., R.H. Stephans, and D.R. Gealy. 1994. Interference between mayweed chamomile (*Anthemis cotula*) and pea (*Pisum sativum*) is affected by form of interference and soil water regime. *Weed Sci.* 42:579-585.
- Perez, F.G.M. and J.B. Masiunas. 1990. Eastern black nightshade (*Solanum ptycanthum*) interference in processing tomato (*Lycopersicon esculentum*). *Weed Sci.* 38:385-388.
- Roberts, H.A. and P.M. Locket. 1978. Seed dormancy and field emergence in *Solanum nigrum* L. *Weed Res.* 38:231-234.
- Rogers, B.S. and A.G. Ogg, Jr. 1981. Biology of weeds in the *Solanum nigrum* complex (*Solanum* selection *Solanum*) in North America. U.S. Dept. Agr. Sci. Ed. Admin. Agr. Rev. Manual. ARM-W-23.
- Snyder, K.M., J.M. Baskin, and C.C. Baskin. 1994. Comparative ecology of the narrow endemic *Echinacea tenesseeensis* and two geographically widespread congeners: Relative competitive ability and growth characteristics. *Intl. J. Plant Sci.* 155:57-65.
- Stoller, E.W. and R.A. Myers. 1989a. Effects on shading and soybean (*Glycine max* L.) interference in *Solanum ptycanthum* (Dun.) (eastern black nightshade) growth and development. *Weed Res.* 29:307-316.
- Stoller, E.W. and R.A. Myers. 1989b. Response of soybeans (*Glycine max* L.) and four broadleaf weeds to reduced irradiance. *Weed Sci.* 37:570-574.
- Swiader, J.M., G.W. Ware, and J.P. McCollum. 1993. Producing vegetable crops. Interstate Publisher, Danville, Ill.
- Thomson, C.E. and W.W. Witt. 1987. Germination of cutleaf groundcherry (*Physalis angulata*), smooth groundcherry (*Physalis virginiana*), and eastern black nightshade (*Solanum ptycanthum*). *Weed Sci.* 35:58-62.
- Wall, D.A., G.H. Friesen, and T.K. Bhati. 1991. Wild mustard interference in traditional and semi-leafless field peas. *Can. J. Plant Sci.* 71:473-480.
- Weller, R.F. and R.H. Phipps. 1978. A review of black nightshade (*Solanum nigrum* L.). *Protection Ecol.* 1:212-239.