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EFFECT OF SHADE AND SOYBEAN (*Glycine max)* ROW WIDTH AND PLANT POPULATION ON NIGHTSHADE SPECIES (*Solanum* spp.).

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Adrienne Marie Rich

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EFFECT OF SHADE AND SOYBEAN [*Glycine max* (L.) Merr] ROW WIDTH AND PLANT POPULATION ON NIGHTSHADE SPECIES (*Solanum spp.*)

By

Adrienne Marie Rich

A THESIS

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ABSTRACT

EFFECT OF SHADE AND SOYBEAN [*Glycine max* (L.) Merr] ROW WIDTH AND PLANT POPULATION ON NIGHTSHADE SPECIES (*Solanum* spp.)

By

Adrienne Marie Rich

Nightshades (*Solanum* spp.) compete with soybean for moisture, nutrients, and light and reduce crop yield and quality. Eastern black nightshade (*Solanum ptycanthum*) is considered to be a shade tolerant weed, implying that emergence and growth may not be affected beneath the soybean canopy, whereas, hairy nightshade (*Solanum sarrachoides*) does not persist in dense shade. Studies were conducted in the field, growth chamber, and greenhouse to determine the effects of shade, soybean row spacing, and plant population on nightshade growth and development. There was no difference in eastern black nightshade emergence regardless of soybean row spacing and population. One application of glyphosate 30 days after planting when soybean was at the V3 stage controlled eastern black nightshade that was 2.5 cm tall both years. Soybean planted in 19 cm rows at populations of 308 000, 432 000, and 556 000 seeds/ha reduced eastern black nightshade growth and reproduction compared to soybean planted at 185 000 seeds/ha in 76 cm rows. Soybean yield was reduced by eastern black nightshade in the 76 cm rows when planted at 432 000 seeds/ha. Eastern black and hairy nightshade growth and reproduction were reduced when grown under reduced irradiances of 63 and 51 $\mu E/m^2/sec$. These results indicate that a 19 cm soybean row spacing or increasing soybean population will reduce the growth and reproduction of these shade tolerant species.

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CHAPTER 1

REVIEW OF LITERATURE

INTRODUCTION

Weed interference can reduce soybean plant dry weight and seed yield (Légère and Schreiber 1989). A common lambsquarters (*Chenopodium album* L.) density of 32 plants per 10 m of soybean row reduced soybean yields by 20% when common lambsquarters were present all season (Crook and Renner 1987). Soybean yield was reduced 46 to 52% and 85 to 92% by densities of 3 and 18 giant ragweed (*Ambrosia trifida* L.) per 10 m of row, respectively (Baysinger and Sims 1991). Coble et al. (1981) found that as few as four common ragweed (*Ambrosia artemiisifolia* L.) plants per 10 m of row reduced soybean yields. Full season interference from 4 common cocklebur (*Xanthium strumarium* L.) per 10 m of row reduced soybean yields by an average of 13% (Bloomberg et al. 1982). In these studies, soybean was planted in 76- or 90-cm rows with plant populations of 335 000 to 450 800 seeds per hectare. Eastern black nightshade (*Solanum ptycanthum*) densities of 2 plants per m^2 did not reduce soybean yield, indicating that eastern black nightshade is not a strong competitor with soybean (Crotser and Witt, 2000).

SOYBEAN ROW SPACING AND PLANT POPULATION

Soybean planted in narrow rows, usually less than or equal to 25 cm, have greater yield potential than soybean planted in wide rows. Ethredge et al.. (1989), reported that soybean yield increased as row spacing decreased from 76-, to 51-, to 25-cm when averaged over two soybean cultivars and three plant populations. In a study conducted by Etheredge et al.. (1989), the number of soybean plants producing seed at harvest was compared to the initial plant population. Soybean seed was planted in 25-, 51-, and 76-cm rows using a cone push planter. Seeds were over planted and thinned to desired populations of 260 200, 390 400, and 520 400 seeds per hectare within two weeks after emergence. When compared across all populations, the number of plants producing seed in the 76-cm rows was only 77% of the initial plant population; whereas, the number of plants producing seeds in the 51- and 25-cm rows was 93 and 97%, respectively. This response was probably due to the more uniform plant distribution in the narrow rows which resulted in less interplant competition during the vegetative stages. The yield increase of narrow row soybean can be attributed to the development of a canopy that provides complete ground cover before the time that pod-fill occurs. Full ground canopies intercept more solar radiation and have greater photosynthesis than do partial ground cover canopies (Shibles and Weber 1966). With the same leaf area index in narrow and wide rows, there was greater light interception in narrow rows because of a more uniform leaf distribution, which resulted in higher yield (Taylor et al.. 1982).

In contrast, Taylor (1980) reported that in years where water was limiting, row spacing had no effect on soybean yield. Soybean were planted in 25-, 50-, 75-, and 100-cm rows at a plant population of 395 000 plants per ha. The increased interception of solar radiation caused by the more even distribution of plants growing in narrow rows resulted in greater water use during the early growing season and less moisture available during pod fill.

Prior to the 1980's, most soybean were planted in wide rows (76 to 104 cm) to allow for the cultivation of weeds. There was no practical advantage of planting soybean in narrow rows because sufficient weed control could not be obtained without cultivation. The narrow choice of herbicides usually did not control all the weed species present so one or two cultivations were necessary to control weeds which were not susceptible to a herbicide. However, if weeds could be controlled early in the growing season, greater season long weed control would be achieved in narrow rows due to faster canopy closure, which would suppress late emerging weeds. Patterson et al.. (1988) reported decreased weed yields in narrow row compared to wide row treatments. Mickelson and Renner (1997) found 30% less weed biomass in narrow rows compared to wide row soybean following postemergence herbicide treatments. Plant populations were 469 500 seeds per ha in 19 cm row spacing and 358 000 seeds per ha in the 76 cm row spacing. Redroot pigweed total leaf area was less in narrow row soybean than in wide row soybean with a soybean population of 385 500 seeds per hectare (Légère and Schreiber 1989). Burnside and Colville (1964) compared soybean row spacings of 25, 50, 75, and 100 cm at a soybean seeding rate of 101 kg/ha, and found that the ground was completely shaded in 36, 47, 58, and 67 days, respectively. Weed control from chloramben treatments was more effective as row spacing decreased. Soybean yields increased as row spacing decreased with soybean in 25 cm rows yielding 39% more than soybean in 100 cm rows.

USE OF GLYPHOSATE IN SOYBEAN

With the introduction of glyphosate for controlling summer annual weeds in glyphosate resistant soybean, growers had a new option for weed management (Delannay et al.. 1995). Glyphosate controls a broad spectrum of grass and broadleaf weeds, but does not have soil residual activity, which allows weeds to emerge after the herbicide application if light and moisture are available. Ateh and Harvey (1999) reported that glyphosate at 310 g ae/ha controlled giant foxtail (*Setaria faberi* Herrm.), common lambsquarters, and velvetleaf (*Abutilon theophrasti* L.) if applied when the weeds were small (<15 cm) and the soybean were at the V2 growth stage. When glyphosate was applied to larger weeds (>15 cm), weeds were consistently controlled in narrow rows only. This was attributed to early canopy closure and shading that reduced subsequent weed emergence. It was noted, however, that for control of larger weeds, it was necessary to use the recommended rate of 810 g ae/ha of glyphosate. Applying glyphosate + imazethapyr, which has soil residual activity, at the V4 stage of soybean did not improve weed control compared to glyphosate alone. Glyphosate alone provided adequate weed control under the conditions of this study.

Producers may postpone application of glyphosate to improve late season weed control. However, delaying the glyphosate application may increase the risk of soybean yield loss due to weed competition and a late application timing may reduce the herbicide efficacy on certain weed species (Gonzini et al.. 1999). Sequential applications of glyphosate may increase overall weed control and reduce the risk of yield reductions due to weed competition. Properly timed sequential applications could eliminate weeds before weed competition occurs and could control later emerging weeds. However, by planting soybean in narrow rows, the need for sequential applications of glyphosate to control late emerging weeds may be eliminated. Young et al. (2001) reported that increasing the glyphosate rate or delaying the glyphosate application did not consistently increase weed control or soybean yield. Glyphosate treatments usually resulted in greater weed control and soybean yield than the standard herbicide treatments; however glyphosate yielded less than the hand-weeded control in some site years, indicating that weed control with glyphosate treatments applied mid-postemergence, late-postemergence and sequential timings was not always sufficient to eliminate weed competition in southern Illinois. Weed control by a single application of glyphosate was improved by the use of 19- or 38- cm rows compared to 76-cm rows, regardless of plant population.

NIGHTSHADE EMERGENCE AND GROWTH

Eastern black nightshade has been a weed problem in soybean fields in the United States for many years (Stoller and Myers 1989a). Eastern black nightshade interferes with harvest and reduces crop quality because the juice from ruptured berries stains the soybean seeds (Quackenbush and Anderson 1984a). Furthermore, nightshade berries are often crushed during harvest, causing the weed seed to cling to the soybean seed which can facilitate the spread of the weed to new areas or act as an initiation site for molds during seed storage. The berries can also pass through combine screens and become a contaminant that is very difficult to separate (Thompson and Witt 1987). Hairy nightshade *(Solanum sarrachoides*) is a weed problem in dry beans (*Phaseolus vulgaris* L.), with dense infestations reducing yield by as much as 77% in Alberta, Canada (Blackshaw 1991). As few as 2 hairy nightshade plants per m significantly reduced dry bean yields. Hairy nightshade is also a weed problem in both transplanted and direct seeded tomato (*Lycopersicon esculentum* Mill.). Photosynthetic rates of both seeded and transplanted tomatoes were reduced by at least 75% by 16 nightshade plants per m compared to the weed free plots. Tomato yield was reduced by 45% in transplanted and 95% in seeded tomatoes by 20 hairy nightshade plants per m (Weaver et al.. 1987).

Shade effectively inhibits the growth of many weeds. The principle characteristic of eastern black nightshade that enables it to be problematic in soybean fields is it's ability to grow in the shaded environment that exists beneath the soybean canopy. Stoller and Myers (1989b), found that eastern black nightshade was able to grow beneath the soybean canopy where irradiance levels were less than 100 $\mu E / m^2 / s$, whereas, velvetleaf, common lambsquarters, and tumble pigweed (*Amaranthus blitoides* L.) could not. Eastern black nightshade adapted to low light intensities beneath the soybean canopy by lowering respiration rate, root-to-shoot ratio, and leaf density, and increasing light absorption efficiency (Stoller and Myers 1989a). Yield of dry beans infested with hairy nightshade was likely affected by competition for light between the two species (Blackshaw et al. 1991). Hairy nightshade was taller than the dry beans for most of the growing season, enabling it to exert a strong shading effect and reduce photosynthetic active radiation (PAR) incidence on the dry beans for the latter part of the growing season (Blackshaw et al., 1991).

The problems associated with eastern black nightshade can be diminished by increasing the competition from soybean plants. Quackenbush and Anderson (1984a), working in Minnesota, reported that eastern black nightshade growth and berry production were greatly reduced once the soybean canopy began to close. The primary reason for this was attributed to the reduction in irradiance due to shading by soybean leaves. It was also noted that if there was a decrease in soybean competition due to defoliation, as might occur with hail or disease, there was an increase in eastern black nightshade growth and berry production. They also reported that in order to assure that eastern black nightshade would not become a problem in soybean, even in instances of hail or disease, control of eastern black nightshade may be required until early August. The ability of eastern black nightshade to survive beneath a soybean canopy creates the potential to become problematic long after other weeds have been forgotten.

Black nightshade (*Solanum nigrum* L.) generally has a reputation of being a late-emerging species, and several authors have noted its ability to continue emerging throughout the summer. This indicates that control of seedlings would be needed through July and August (Rogers and Ogg 1989). Generally, eastern black nightshade emerges in the spring when the daily maximum air temperature approaches 20°C (Ogg and Dawson 1984, Roberts and Lockett 1978). Ogg and Dawson (1984), working in Washington, found there were significant differences in the patterns of emergence between eastern black nightshade and hairy nightshade. Most of the eastern black nightshade seedlings emerged within a two month period in the spring, whereas, seedlings of hairy nightshade had several peaks in emergence from late April through late July and continued to emerge throughout the growing season. Quackenbush and Anderson (1984b) found similar results in Minnesota. These results may indicate that eastern black nightshade is not a late emerging weed as previously suggested. Roberts and Lockett (1978) working in England, reported that hairy nightshade emergence peaked in May or June, declined in July and August, and ceased in September. Cultivation of the soil increased emergence and could cause a second peak of emergence in July. Moist weather conditions also increased the number of germination flushes. Ninety percent of eastern black nightshade emerged in April and almost none after June in Washington and Minnesota (Ogg and Dawson 1984, Quackenbush and Anderson 1984b). Weed seed placement below 2.5 cm significantly reduced germination of black nightshade (*Solanum nigrum*) regardless of soil type (Vandeventer et al.. 1982).

Nightshade seeds became viable within a few weeks after anthesis. Eastern black nightshade seeds became viable 2 to 4 weeks after anthesis, with 30% germination after 4 weeks, 80% germination after 6 weeks, and 91% germination after 8 weeks (Thomson and Witt 1987). Quackenbush and Anderson (1984b) found similar results for eastern black nightshade, but found that five weeks were required after anthesis before hairy nightshade seeds were viable. Shade during the growth and production of eastern black nightshade increased the time required for seeds to become viable by about 50% if the berries were dried before seed removal. Shade did not affect the time for seeds to become viable if seeds were removed from fresh berries (Stoller and Myers 1989b).

Freshly harvested hairy nightshade seeds subjected to diurnally fluctuating temperatures of 20 to 35°C failed to germinate. Hairy nightshade seed stored for several months in dry, warm conditions, or moist conditions at 4°C, or buried in the field over winter, developed the capability for germination at constant 25 or 30°C and at alternating temperatures (Roberts and Boddrell 1983).

Generally, black nightshade seeds will not germinate at temperatures below 20°C or above 40°C (Givelberg and Horowitz 1984, Roberts and Lockett 1978). Keely and Thullen (1983) found that black nightshade seeds produced late in the season required higher temperatures for optimum germination than did seeds produced early in the growing season. Germination in light of dry-stored seeds of eastern black nightshade was maximum at constant 30°C or at alternating 20/30°C (Thomson and Witt 1987). In the dark, eastern black nightshade seeds germinated poorly over all temperature regimes except alternating temperatures of 10/30°C and 20/30°C where 58% and 61%, respectively, of the seeds germinated. Bugert and Burnside (1972) reported that hairy and eastern black nightshade seeds germinated in the field when soil temperatures were between 20° and 46° C. The optimum temperature for germination of both species was 30°C.

Nightshades begin to emerge in the early spring and flowers appear 7 to 9 weeks later (Keely and Thullen 1983). Eastern black nightshade grown without soybean competition began to flower 1 to 3 weeks after reaching the 5 leaf- stage and in some cases within six weeks after seeds were planted (Quackenbush and Anderson 1984a). Black nightshade growing without crop interference and planted April 1 through July 1 produced an average of 1000 berries per plant, whereas plants from seeds planted March 1, August 1, and September 1 produced 410, 620, and 30 berries, respectively, per plant (Keely and Thullen 1983). Eastern black nightshade plants grown without intra- or interspecific interference produced in 20 weeks 240 g dry weight and 5,960 berries per plant. Conversely, plants grown under similar conditions but under 94% shade, produced only 3 g dry weight and 23 berries per plant (Stoller and Myers 1989a).

Eastern black nightshade that emerged with soybean and grew in the open spaces between rows 75 cm apart produced 43 g dry weight and 264 berries per plant, whereas, nightshades that grew between rows spaced 33 cm apart produced an average of less than 1 g dry weight and less than 1 berry per plant. Berry production declined under shade because flowers were aborted (Stoller and Myers 1989b). It is important to note that even the smallest eastern black nightshade plants produced some reproductive growth by the last harvest date, contributing seeds to the soil bank for future infestations. The threshold to prevent berry production was about 94% shade, a level commonly found beneath soybean canopies during the middle of the growing season (Quackenbush and Anderson 1984a). In mid-July in Minnesota, less than 5% of the photosynthetically active radiation (PAR) of full sun reached the ground between narrow spaced (18 cm) rows of soybean planted at 10 seeds per m of row, whereas, 76% of full sun PAR reached the ground between wide spaced (76 cm) rows of soybean planted at 30 seeds per m of row (Quackenbush and Anderson 1984a). Eastern black nightshade planted in May with soybean in narrow rows (18 cm) produced 50% fewer berries than did plants in soybean in wide (76 cm) rows. Stoller and Myers (1989b) noted that a large proportion of the berries were produced late in the season after soybean leaf abscission regardless of the plants' positions relative to the soybean row, emergence dates, or row width. They attributed the large production of berries to the plants response to increased irradiance that was experienced during this short period. Berry production of eastern black nightshade and hairy nightshade is also enhanced in the fall because the nightshade is not killed by light frosts and plants continue to produce berries after crop senescence (Stoller and Myers 1989b). Quackenbush and Anderson (1984b) reported that eastern black nightshade was more frost tolerant than hairy nightshade.

Eastern black nightshade is a prolific seed producer with 50 to 110 seeds per berry (Rogers and Ogg 1989). Hairy nightshade berries contain 10 to 35 seeds per berry. Keely and Thullen (1983) reported that an *S. nigrum* plant can produce over 30,000 seeds in a season. Once the soil seed bank includes seeds from these *Solanum* species, these weeds have the potential to infest the site for a number of years. Toole and Brown (1946), working in England with plants identified as *S. nigrum*, showed that black nightshade seeds in clay pots filled with soil and buried outdoors retained viability after 39 years. In contrast, Bassett and Munro (1985), working with hairy nightshade and eastern black nightshade, reported that 90% of the nightshade seed tested for longevity in soil was viable for 5 years after collection and then the viability percentage dropped successively to 73, 27, and 2% over the next 3 years. Roberts and Lockett (1978) found about 11% of black nightshade seeds in cultivated soil were viable after 5 yr. Nightshades can only reproduce via seed so it is important to understand factors such as seed longevity, germination, and emergence, as well as seed production when formulating control measures of these weed species.

Nightshades are not strong competitors against soybean (Quackenbush and Anderson, 1984a). In competition with soybean, eastern black nightshade emergence and survival was greatly reduced once the soybean canopy began to close. Of the 72 plots having nightshade seeds planted into wide- or narrow-row soybean after mid-July, only 3 contained a nightshade plant by soybean harvest time. Eastern black nightshade that was grown without soybean interference was able to complete its life cycle in ten weeks or less. Thirty-three to 47% of the total dry weight was allocated to berry production. These nightshade plants produced over 700 berries per plant and 800,000 seeds. In contrast, those planted with soybean produced less than 60 berries and only 2500 seeds per plant. Those nightshades that were planted 3 weeks or more after soybean produced 10 or fewer berries (Quackenbush and Anderson 1984a). Stoller and Myers (1989a) found that eastern black nightshade growth was closely associated with the total irradiance received by the plants. Shade structures were constructed in the field with saran mesh cloth rated for the amount of solar radiation intercepted. Shoot growth of eastern black nightshade was reduced by 48, 83, and 98% by shade levels of 60, 80, and 94%, respectively. Berry number was reduced by 48, 87, and 99% at the same shade levels and berry production constituted 53, 59, and 40% of the total biomass when grown under these shade levels. At the lowest growth irradiance, eastern black nightshade utilized nearly half of its biomass in harvesting the available light, an essential function for a plant that survives extended periods under the soybean canopy.

Small seeded crops such as tomatoes, however, are not strong competitors and yields can be reduced severely where nightshades are dense (Tan and Weaver 1997). Weaver et al. (1987) reported an 80% yield loss in direct seeded tomatoes from four eastern black nightshade per m^2, but only 25 to 60% yield loss from the same weed density in transplanted tomatoes. McGiffen et al.. (1992) reported that five nightshade plants per m^2 can significantly reduce the yield of tomato. Eastern black nightshade at five plants per m^2 resulted in only 21 tomatoes per plant, as opposed to 51 fruit per plant when tomatoes were weed free. Tomato fruit yield declined exponentially as eastern black nightshade density increased. Eastern black nightshade reduced tomato yields when it grew taller than the canopy and shaded the young, actively photosynthesizing tomato leaves. Blackshaw (1991) reported that as few as two hairy nightshade plants per m significantly reduced dry bean yield. Interference from hairy nightshade during the first three weeks after emergence was enough to reduce dry bean yield. Six to nine weeks of weed free maintenance are needed to attain dry bean seed yields that are comparable to the weed free. Hairy nightshade seed production per plant decreased from 52,000 to 1900 seeds as hairy nightshade density increased from 2 to 100 plants per meter of bean row.

At six weeks after dry bean emergence, only dry bean density affected hairy nightshade biomass. In that case, less biomass was attained when dry beans were grown at 48 than at 24 plants per m^2. As the growing season progressed, the competitive effects of dry bean on hairy nightshade became more evident. At maturity, hairy nightshade biomass was progressively reduced as dry bean row spacing was reduced from 69 to 46 to 23 cm. Additionally, hairy nightshade biomass was reduced when dry bean density was increased from 24 to 48 plants per m^2. At a density of 48 plants per m^2, dry bean yield progressively increased as row spacing was reduced from 69 to 23 cm. Narrow row spacing and a higher plant density allowed dry bean to capture more PAR at any one time and also resulted in more complete canopy closure earlier in the growing season. Yield of dry beans infested with hairy nightshade was likely affected by competition for light between the two species (Blackshaw et al. 1999).

EFFECT OF SHADE ON PLANT GROWTH

Crops and weeds show varying degrees of shade tolerance. In a study comparing soybean and weeds commonly associated with soybean, eastern black nightshade, tumble pigweed, and common cocklebur were the most photosynthetically efficient under low-growth irradiance due to a combination of physiological and morphological adaptations (Regnier et al.. 1988; Stoller and Myers 1989a). In contrast to eastern black nightshade, hairy nightshade, another nightshade species that is common in Michigan, does not appear to persist in dense shades (Tan and Weaver 1997). The presence of a leaf canopy alters the quantity as well as the spectral distribution, or quality, of light underneath it. Many plants possess plasticity to acclimate to reduced light conditions by redistribution of dry matter, altered leaf anatomy, decreased respiration rates, decreased enzyme activities, and decreased electron transport capacity (Holt 1995). Reductions in yield of processing tomato were greater when grown in competition with eastern black nightshade compared to black nightshade due to the greater height of eastern black nightshade. PAR at the top of the tomato canopy was positively correlated with yield and negatively correlated with eastern black nightshade density (McGiffen et al.. 1992). When plant environments change from high light to a shaded environment (i.e. when a canopy closes) many weeds respond with adaptations that reduce the growth-limiting effects of shading. Increased leaf area ratio (LAR) and plant height are common responses to shade that may offset reductions in photosynthetic rate and biomass production that commonly occur. However, seed production generally decreases when reductions in light are extreme (Holt 1995).

Leaves absorb light in the blue and red regions and reflect or transmit in the green and far red regions of the spectrum. With increasing depth in a plant canopy, light is enriched in the far red wavelengths and has a lower red: far red ratio. The spectral photon distribution of radiation within a canopy is severely depleted in the 400 to 700 nm range and enhanced in wavelengths over 700 nm (far red light). The morphological responses seen by plants in response to reduced irradiance have been shown to be triggered by phytochrome in response to the low red: far red ratios under canopies (Taiz and Zieger 2002). These morphological responses include stem elongation, flowering, and changes in stomatal conductance or plant anatomy. Leaf thinning in shaded conditions has also been attributed to an increase in the ratio of R: FR light, but may also result from a decrease of blue light.

Weed success depends on survival and some level of reproduction to continue the species. Knowledge of the responses of hairy nightshade and eastern black nightshade to different levels of light quantity and quality will allow for the development of management techniques to enhance control of these weed species.

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CHAPTER 2

NARROW ROW SPACING INCREASED CONTROL OF EASTERN BLACK NIGHTSHADE (*Solanum ptycanthum*) IN GLYPHOSATE- RESISTANT SOYBEAN (*Glycine max*) IN MICHIGAN

Abstract. Field studies were conducted to evaluate the effect of soybean row spacing and soybean populations on the emergence and growth of eastern black nightshade in glyphosate-resistant soybean. Eastern black nightshade emerged 15 to 20 days after soybean planting and emergence ceased approximately 40 days after planting when soybean were at the V5 stage of growth. There was no difference in eastern black nightshade emergence regardless of soybean row spacing and populations in all site years. One application of glyphosate controlled eastern black nightshade in this study. Soybean leaf area index was greatest for soybean planted in 19 cm rows at the peak of the growing season, regardless of soybean population. Soybean planted in 19 cm rows at populations of 308 000, 432 000, and 556 000 seeds/ha were more competitive than soybean planted at 185 000 seeds/ha in 76 cm rows. Seeding rates of 308 000 and 432 000 seeds/ha effectively reduced eastern black nightshade growth in 76 cm rows. Soybean yield at East Lansing in 2001 was not greater in narrow rows compared to 76 cm rows when eastern black nightshade was controlled. Eastern black nightshade densities of 2 to 7 plants/m^2 reduced the yield of soybean planted at populations of 308 000 and 556 000 in 19 cm rows and 185 000 seeds/ha in 76 cm rows in 1 of 3 site years.

KEY WORDS: soybean populations, row spacing, eastern black nightshade (*Solanum ptycanthum*)

INTRODUCTION

Weed interference with soybean can reduce yield and soybean plant dry weight (Légère and Schreiber 1989). As few as four common ragweed (*Ambrosia artemisiifolia* L.) plants per 10 m of row reduced soybean yields (Coble et al. 1981). Full season interference from four common cocklebur (*Xanthium strumarium*) per 10 m of row reduced soybean yields by an average of 13% (Bloomberg et al.. 1982). Soybean yield was reduced 46 to 52% by 3 giant ragweed (*Ambrosia trifida* L.) plants per 10 m of row, respectively (Baysinger and Sims 1991). Common lambsquarters (*Chenopodium album*) at a density of 32 plants per 10 m of soybean row reduced soybean yields by 20% when common lambsquarters were present all season (Crook and Renner 1987). Eastern black nightshade (*Solanum ptycanthum*) densities of 2 plants per m^2 did not reduce soybean yield, indicating that eastern black nightshade is not a strong competitor with soybean (Crotser and Witt, 2000).

In recent years, growers have become interested in planting soybean in narrow row widths because of potentially higher yields and better weed control. Soybean planted in 25 cm rows yielded 39% more than soybean in 100 cm rows when planted at 101 kg/ha (Burnside and Coleville 1964). Ethredge et al. (1989), reported that soybean yield increased as row spacing decreased from 76-, to 51-, to 25-cm when averaged over two soybean cultivars and three plant populations. The yield increase of narrow row soybean can be attributed to the development of a canopy that provides complete ground cover before the time that pod-fill occurs. Full ground canopies intercept more solar radiation and have greater photosynthesis than do partial ground cover canopies (Shibles and Weber 1966). With the same leaf area index in narrow and wide rows, there was greater light interception in narrow rows because of a more uniform leaf distribution, which resulted in higher yield (Taylor et al. 1982).

When soybean are planted in narrow rows, weed biomass is reduced (Patterson et al. 1988). Post emergence herbicide treatments in narrow rows resulted in 30% less weed biomass than the same treatments in wide row soybean (Mickelson and Renner 1997). Plant populations were 469 500 seeds per ha in 19 cm row spacing and 358 000 seeds per ha in the 76 cm row spacing. Redroot pigweed total leaf area was reduced in narrow row soybean compared to wide row soybean (Légère and Schreiber 1989).

Glyphosate is now widely used for controlling summer annual weeds in glyphosate resistant soybean (Delannay et al. 1995). Glyphosate controls a broad spectrum of grass and broadleaf weeds, has a favorable environmental profile, a low mammalian toxicity, and is an alternative to the acetolactate synthase inhibiting herbicides. However, glyphosate does not have soil residual activity, which allows weeds to emerge after herbicide application if light and moisture are available. In Wisconsin, weeds were consistently controlled in 20 cm rows due to early canopy closure and shading of subsequent flushes (Ateh and Harvey 1999). Adding imazethapyr, which has soil residual activity, to a glyphosate application at the V4 stage of soybean (Ritchie et al. 1997) did not improve weed control compared to glyphosate alone.

Sequential applications of glyphosate may increase overall weed control and reduce the risk of yield reductions due to weed competition (Gonzini et al. 1999). Properly timed sequential applications could eliminate weeds before weed competition occurs and could control later emerging weeds. However, by planting soybean in narrow rows, sequential applications of glyphosate to control late emerging weeds may be unnecessary. Weed control by a single application of glyphosate was improved by the use of 19- or 38- cm rows compared to 76-cm rows in southern Illinois (Young et al. 2001).

Shade effectively inhibits the growth of many weeds. Eastern black nightshade can be a problem in soybean fields because it can grow in the shaded environment that exists beneath the soybean canopy (Stoller and Myers 1989a). Eastern black nightshade interferes with soybean harvest and reduces crop quality because the juice from ruptured berries stains soybean seeds (Quackenbush and Anderson 1984a). Eastern black nightshade problems, however, can be reduced by increasing the competition from soybean plants. Eastern black nightshade emergence and survival was greatly reduced once the soybean canopy began to close. Nightshades planted 3 wk or more after soybean produced 10 or fewer berries per plant (Quackenbush and Anderson 1984a). By narrowing rows to 38 cm, eastern black nightshade growth and berry production was reduced by 50% in Illinois (Stoller and Myers 1989b). However, even the smallest eastern black nightshade plants produced some reproductive growth by the last harvest date, contributing seeds to the soil seed bank for future infestations as well as creating the potential to stain soybean seed and impede harvest (Crotser and Witt 2000).

The objectives of this study were to determine the influence of soybean row spacing and soybean population on the emergence and growth of eastern black nightshade. The influence of soybean plant population on eastern black nightshade emergence and growth has not been reported previously. Furthermore, we determined if a residual herbicide was necessary for season long control of eastern black nightshade following a glyphosate application in soybean planted at three populations in two row spacings. Residual herbicides are an expense to the grower and can influence crop rotation the following year. Residual herbicides may not be necessary to stop eastern black nightshade emergence and growth in high populations of soybean planted in narrow rows because of faster canopy closure resulting in reduced irradiance.

MATERIALS AND METHODS

Field experiments were conducted in 2001 and 2002 to evaluate the emergence and growth of eastern black nightshade in glyphosate-resistant soybean. In 2001 and 2002, research was conducted at the Michigan State University Crop and Soil Science Research Farm in East Lansing, MI. In 2002, research was conducted at this farm and at the Michigan State University Horticultural Experiment Station in Clarksville, MI. The soil at East Lansing was a Capac sandy clay loam (fine-loamy, mixed, mesic Aeric Ochraqualfs) with 2.5% organic matter and a pH of 6.4 in 2001. This site was moldboard plowed the previous fall and field cultivated twice in the spring. In 2002, the soil at East Lansing was a Capac sandy clay loam with 2.5% organic matter and a pH of 7.0. The soil at Clarksville was a Lapeer loam (coarse-loamy, mixed, mesic Mollic Haplaquepts) with 1.5% organic matter and a pH of 6.6. This site was chisel plowed and field cultivated twice in the spring of 2002.

In 2001, DeKalb CX 242 soybean were planted in 19 and 76 cm rows at 308 000, and 432 000 seeds ha^{-1}. In 2002, DeKalb CX 23-51 soybean were planted at populations of 308 000, 432 000, and 556 000 seeds ha^{-1} in 19 cm rows and 185 000, 308 000, and 432 000 seeds ha^{-1} in 76 cm rows. Both varieties were mid-group 2 soybean. Soybean were planted in 19 cm row spacings with a Great Plains Solid Stand 10[1] grain drill in 2001 and a John Deere 1560[2] grain drill at East Lansing and a John Deere 750 grain drill at Clarksville in 2002. Soybean were planted in 76 cm row spacing with a John Deere 7200 Max-Emerge® 2 planter at East Lansing both years and a John Deere 7000 planter at Clarksville in 2002. Plots at East Lansing were 3 m wide and 9.1 m long in 2001 and 3

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[1] Great Plains Manufacturing Inc., P.O. Box 218, Assaria, KS 67416.

[2] Deere and Co., 501 River Drive, Moline, IL 61265-1100.

m wide and 10.7 m long in 2002. Plots in Clarksville were 4.6 m wide and 12.2 m long in 2002.

Eastern Black Nightshade Emergence

Eastern black nightshade seed[3] was spread across the field to ensure a uniform population at each location in each year. Quadrats (0.19 m^2) were placed within and between the soybean rows in the plots receiving the glyphosate application. Quadrat locations were marked at the time of the first emergence count so that the same area was evaluated each time. Seedlings were left undisturbed as they were counted. Emergence counts were taken weekly throughout the growing season.

Herbicide Applications

A preemergence application of cloransulam methyl at 17.7 g a.i. per hectare was applied to the entire field sites both years to control other broadleaf weeds besides eastern black nightshade; cloransulam methyl has no effect on eastern black nightshade (Anonymous 2003). Postemergence herbicide treatments each year included glyphosate at 650 g ae ha^{-1}, glyphosate + imazethapyr at 650 g ae ha^{-1} and 70 g ai ha^{-1}, respectively, and an untreated control. All herbicide treatments included 21 g ammonium sulfate per L of spray solution. A weed free plot was present in each replication that was not taken to yield for the purpose of soybean canopy measurements and emergence counts. The weed free plots received an application of glyphosate as needed. All postemergence treatments were applied to soybean at V3 and eastern black nightshade with 3 to 6 leaves and 2.5 cm tall.

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[3] V & J Seed, P.O. Box 82, Woodstock, IL 60098.

Preemergence herbicide applications were made with a Wilmar sprayer traveling at 10.3 km/h and delivering 187 L/ha at 207 kPa of pressure on 14 May 2001 and 15 May 2002 in East Lansing. Preemergence herbicide application in Clarksville was made with a tractor mounted compressed air sprayer traveling at 6.3 km/h and delivering 178 L/ha at 207 kPa of pressure on 22 May 2002. Postemergence herbicide applications were made with a tractor mounted compressed air sprayer traveling at 6.3 km/h and delivering 178 L/ha at 207 kPa of pressure on 23 June 2001 and 22 June 2002 in East Lansing and 24 June 2002 in Clarksville. Treatments were made with 8003 flat fan nozzles[4] on a 51 cm spacing at 61 cm above the crop and weed canopy. Air temperature at East Lansing was 28° C with 48% relative humidity in 2001 and 28° C with 51% relative humidity in 2002 at the time of application. Air temperature at Clarksville was 31° C with 35% relative humidity at the time of application.

Soybean Canopy Development

The amount of light transmitted through the soybean canopy was measured every 1 to 2 weeks at or near solar noon at each site beginning in early July until the canopy began to senesce in early September. Measurements were taken only in weed free plots using a SunScan Canopy Analysis System.[5] The SunScan system consists of three components: 1) a wand that is 1 m long and 13 mm wide with sensors placed every 15.6 mm along the length of the wand with a spectral response of 400-700 nm to measure light beneath the crop canopy, 2) a tripod-mounted sensor to measure both incident and diffuse light above the crop canopy, and 3) a handheld Psion Workabout datalogger[6] that combined simultaneous measurements of light above and beneath the crop canopy. Light

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[4] Teejet flat fan tips. Spraying Systems Co., North Ave. and Schmale Road, Wheaton, IL 60188.
[5] Delta-T Devices LTD, 128 Low Road, Burwell, Cambridge CB5 0EJ, England.
[6] Gylling Data Management Co. Inc., 405 Martin Blvd., Brookings, SD 57006.

transmission, as a percent of incident, was automatically calculated as each measurement was taken perpendicular to the soybean row from the weed free plots.

Eastern Black Nightshade Biomass

Eastern black nightshade biomass was sampled on 20 October 2001 and 1 October 2002 in East Lansing and on 27 September 2002 in Clarksville by harvesting all aboveground portions of each eastern black nightshade plant from a 0.19 m^2 quadrat placed randomly within the plot. Eastern black nightshade was harvested and counted from two areas per plot, oven dried, and weighed.

Microplots

In 2002, microplots were established in East Lansing and Clarksville to study further the effects of soybean population and row spacing on nightshade growth and development. These microplots were 3.8 m x 3.8 m in size. Soybean were over seeded in 19 cm and 76 cm rows and thinned to desired populations of 308 000, 432 000, and 556 000 plants per hectare in the 19 cm rows and 185 000, 308 000, and 432 000 plants per hectare in the 76 cm rows. Postemergence herbicide treatments at each location included glyphosate at 650 g ae ha^{-1} and an untreated control. Postemergence herbicide applications were made with a tractor mounted compressed air sprayer traveling at 6.3 km/h and delivering 178 L/ha at 207 kPa of pressure on 22 June 2002 in East Lansing and 24 June 2002 in Clarksville when soybean were at V3 stage of growth and nightshade was 2.5 cm tall. Treatments were made with 8003 flat fan nozzles[7] on a 51 cm spacing at 61 cm above the crop and weed canopy. Nightshade biomass measurements (plant number, total dry weight, berry dry weight) were taken on July 9, August 6, and September 27 at East Lansing and July 10, August 8, and October 1 at Clarksville by

[7] Teejet flat fan tips. Spraying Systems Co., North Ave. and Schmale Road, Wheaton, IL 60188.

harvesting all aboveground portions of each eastern black nightshade plant from a 0.19 m^2 quadrat placed randomly within the microplot. Eastern black nightshade was counted, oven-dried, and weighed. Berries were weighed separately from the leaves and stems for the August and October harvest dates. Soybean yield was determined by harvesting the center rows of each plot with a plot combine. Soybean yields were taken on 1 October 2002 at both locations. Seed yields were adjusted to 13% moisture.

Soybean Yield

Soybean yield was determined by harvesting the center rows of each plot with a Massey 8XP self propelled plot harvesting combine with onboard harvest yield and moisture equipment. Soybean was harvested on 28 October 2001 and 1 October 2002 at both East Lansing and Clarksville. Seed yield was adjusted to 13% moisture. All eastern black nightshade plants remaining in the plots were removed by hand prior to harvest so that eastern black nightshade berries would not be weighed with the soybean seed.

Statistical Analysis

The experimental design was a split-split plot design with four replications. The main plot was row spacing, the sub-plot was soybean population, and the sub-sub-plot was herbicide treatment. Data were subjected to analysis of variance using the PROC MIXED procedure in SAS and means were separated using Fishers Protected LSD at $\alpha = 0.05$. Results are presented separately by year and location since additional soybean populations were included in 2002. Results are presented separately for each location in 2002 where year*location interactions exist.

RESULTS AND DISCUSSION

Eastern Black Nightshade Emergence

Eastern black nightshade emerged 15 - 20 days after soybean planting in 2001 and 2002 (Figure 1, 2, 3). In both years, emergence of black nightshade ceased approximately 40 days after planting when soybean were at the V5 stage (Ritchie et al. 1997). Ogg and Dawson (1984) reported that most of the seedlings of eastern black nightshade emerged within a 2 month period in the spring. Similar results were reported by Roberts and Boddrell (1983) and Roberts and Lockett (1978) working in England, and Quackenbush and Anderson (1984) in Minnesota. This indicates that eastern black nightshade may not be a late emerging species as previously reported. Optimum germination of eastern black nightshade was at a constant 30°C or at alternating temperatures of 30/20° C (Thompson and Witt, 1987). Bugert et al. (1973) reported that eastern black nightshade seeds germinated in the field when soil temperatures were between 20° C and 46° C, but the optimum temperature for emergence was 25° to 30°C. On 8 August 2001, the maximum soil temperature was 41° C at East Lansing. On 4 July 2002, the maximum soil temperature was 29° C at East Lansing and 33° C at Clarksville. Rainfall was above average in May for both 2001 and 2002 (Table 1), however, rainfall was below average in June of both years at East Lansing and July 2002 at Clarksville. At East Lansing, eastern black nightshade may have ceased to emerge in 2001 due to dry soil conditions and high soil temperatures. In 2002, at East Lansing and Clarksville, eastern black nightshade probably ceased to emerge due to dry soil conditions.

There was no difference in eastern black nightshade emergence due to soybean row spacing and population in 2001 (Figure 1) or in 2002 at either location (Figure 2).

The total number of seedlings that emerged varied widely between years and locations. Natural populations of eastern black nightshade seeds in the soil as well as the seeded population probably account for emergence during this time period. It appears that shading from the soybean had no effect on eastern black nightshade emergence. We observed no difference in eastern black nightshade emergence adjacent to or between the soybean rows in our biweekly quadrant counts. Light is required for the germination of eastern black nightshade seeds. Thompson and Witt (1987) reported that in the dark, eastern black nightshade seed germinated poorly over all temperature regimes. Eastern black nightshade germination was enhanced by light and within the visible spectrum red light was most effective in enhancing germination (Givelberg and Horowitz 1984). Light was not limited by the soybean canopy in the forty days following soybean planting because at 50 days after planting (DAP) the LAI was still less than one (Figures 3 and 4). Therefore, eastern black nightshade had light available for germination and emergence.

Herbicide Applications

One application of glyphosate at the V3 stage of soybean controlled eastern black nightshade in 2001 and 2002. Since eastern black nightshade did not emerge later in the growing season after the herbicide application, a residual herbicide, such as imazethapyr, was not needed for season long control of eastern black nightshade in this study. Rainfall in July and August of 2001 and in 2002 was below average in both years of this study (Table 1). This may have contributed to the lack of late season eastern black nightshade emergence. In a year with normal rainfall, a residual herbicide would be needed to control late emerging eastern black nightshade if emergence was not limited by high soil temperature. It would be of interest to study eastern black nightshade emergence in a field with no soybean canopy to determine if eastern black nightshade would continue to emerge throughout the summer if adequate rainfall occurred. Furthermore, the study of seed emergence patterns collected from plants growing in a single field would be of interest to determine if Keely and Thullen's (1983) report of late forming seed requiring higher temperatures for germination is supported, and if eastern black nightshade seed from shaded areas requires a lengthier after ripening period (Stoller and Myers 1989b). These factors could result in a species 'shift' in narrow row soybean to eastern black nightshade populations that emerge later when soil temperatures are warmer.

Soybean Canopy Development

In 2001, early in the growing season, soybean planted in 76 cm row spacing had a higher leaf area index (LAI) than those planted in the drilled rows (Figure 3a). However, at the peak of the soybean canopy (approximately 105 days after planting), soybean planted in 19 cm rows at both populations had greater LAI than those planted in the 76 cm row spacing. This indicates that soybean planted in 19 cm row spacings have a greater ability to compete for light with eastern black nightshade than those planted in 76 cm row spacings.

We saw a similar pattern in 2002 at both locations, with soybean planted in the 19 cm row at populations of 432 000 and 556 000 seeds/ha having a greater LAI than those planted in the 76 cm row spacing (Figure 3b and 3c). However, the difference in LAI was seen much earlier in 2002 (50 to 70 DAP) than in 2001 (105 DAP), indicating that in 2002, eastern black nightshade growth would have been affected for a longer period of time. At the end of the growing season in 2002 at Clarksville, soybean planted in 76 cm rows had a greater LAI than those in the 19 cm row spacing. This is because of some soybean lodging that occurred in the drilled soybean.

Therefore, row spacing had a greater influence on LAI than plant population. In fact, soybean population had a negligible affect on canopy development and closure. Eastern black nightshade growth will be suppressed by planting in narrow rows due to increased soybean LAI, regardless of soybean population. However, the lack of soil moisture may have inhibited soybean growth and yield potential, particularly at 556 000 seeds/ha in 19 cm rows. Taylor (1980) reported that in years where water is limiting, row spacing had no effect on soybean yield. The increased interception of solar radiation caused by the more even distribution of plants growing in narrow rows resulted in more water use during the early growing season and less water remaining during pod fill. Higher populations, regardless of row spacing, would therefore not be able to maximize canopy development and yield in years where rainfall is limited in August during time of pod-fill (Table 1).

Eastern Black Nightshade Biomass

In 2001, soybean row spacing or plant population did not reduce the density or dry weight of eastern black nightshade in October (Table 2). Densities of eastern black nightshade in October were approximately 85% less than densities measured in June (Figure 1). This indicates that there is attrition of eastern black nightshade plants when in competition with soybean. Self thinning due to intraspecific competition has been reported extensively in the ecological literature. The term self thinning refers to the density dependent mortality in plant populations. The severity of self thinning is affected by environmental conditions such as moisture and light (Harper 1977). However, in most weed competition studies in soybean, the established weed density are reported, and not the weed density at the time of harvest.

In 2002, eastern black nightshade density within each row spacing was not affected by soybean population. However, eastern black nightshade density was reduced in the 19 cm rows compared to the 76 cm row spacing at East Lansing, when averaged over plant populations. At Clarksville, soybean planted at 556 000 seeds/ ha in the 19 cm row spacing had a significantly lower eastern black nightshade density than those planted at 185 000 seeds/ ha in the 76 cm row spacing (Table 3). Since there were no differences in eastern black nightshade emergence in May and June due to soybean row spacing or population, early season eastern black nightshade emergence will not be influenced by soybean row spacing or population.

Eastern black nightshade total dry weight per plant at East Lansing and Clarksville was reduced in the 19 cm row spacing at all populations compared to 185 000 seeds/ha 76 cm row spacing (Table 3). Stoller and Myers (1989b) found that eastern black nightshade that emerged with soybean and grew in the open spaces between rows 75 cm apart produced 43 g dry weight and 264 berries per plant, whereas, nightshades that grew between rows spaced 33 cm apart produced an average of less than 1 g dry weight and less than 1 berry per plant. Quackenbush and Anderson (1984) reported that eastern black nightshade planted in May with soybean in narrow rows (18 cm) produced 50% fewer berries than did plants in soybean in wide (76 cm) rows. Our results indicate that soybean planted in the 19 cm row spacing, regardless of soybean population, are more competitive than soybean planted at 185 000 seeds/ha in 76 cm rows. Therefore, seeding rates of 308 000, 432 000 and 556 000 seeds/ha in drilled soybean effectively reduced eastern black nightshade growth. Seeding rates of 308 000 and 432 000 effectively reduced eastern black nightshade growth in 76 cm rows also. It would be of interest to plant soybean at 185 000 seeds/ha in 19 cm rows to determine if this low of a population would supress eastern black nightshade growth.

Microplots

In 2002 at East Lansing, planting soybean in 19 cm rows did not reduce the density of eastern black nightshade in July compared to 76 cm rows, regardless of soybean plant population (Table 4a). There were no differences in soybean canopy at this point of the growing season, so there was light available for nightshade growth, regardless of row spacing or plant population. However, by August (p= 0.0414) and October (p=0.0181), eastern black nightshade density was significantly reduced in 19 cm rows compared to 76 cm rows, regardless of soybean plant population. LAI of soybean in 19 cm row spacings was greater than the LAI of soybean in 76 cm soybean. Furthermore, there was more light available in soybean planted in 76 cm row spacing at 185 000 seeds/ha population for eastern black nightshade growth compared to light at 432 000 seeds/ha in 76 cm rows (Figure 4a and 4b). At Clarksville, eastern black nightshade density was greater in the 76 cm rows at populations of 185 000 and 308 000 seeds/ha compared to the 19 cm rows at a population of 556 000 seeds/ha in July (Table 4b). In August, the soybean planted in 76 cm rows at a population of 432 000 seeds/ha had a significantly higher eastern black nightshade density compared to soybean planted in 19 cm rows at 308 000 and 432 000 seeds/ha. By October, eastern black nightshade density was significantly (p= .0353) greater in 76 cm rows at a population of 308 000 seeds/ha compared to 432 000 seeds/ha in 19 cm rows. This difference may be attributed to eastern black nightshade attrition in the 19 cm row spacing. The soybean canopy was greatest in 76 cm rows in Clarksville in late August due to soybean lodging that took place in the 19 cm row soybean, which allowed for more light available for nightshade growth in the 19 cm rows late in the growing season.

The total dry weight per plant of eastern black nightshade at East Lansing was reduced in the 19 cm compared to 76 cm rows in July and August, but not in October (Table 5). Berry dry weight at East Lansing was also similar in 19 cm compared to 76 cm rows, although there was a strong trend to indicate that eastern black nightshade growing in 19 cm rows produced fewer berries than those in 76 cm rows (Table 6). In contrast, at Clarksville, eastern black nightshade total dry weight per plant was reduced in 19 cm rows compared to 76 cm rows in all three harvest months, when averaged over row spacings (Table 5). By October, the dry weight of eastern black nightshade berries produced in 19 cm row soybean was significantly reduced compared to berry dry weight in the 76 cm rows.

The density of eastern black nightshade density in microplots was greater at East Lansing than at Clarksville throughout the growing season. There was probably more intraspecific competition at East Lansing compared to Clarksville. This is evident by looking at the eastern black nightshade dry weight per plant. The plants at Clarksville were larger than those at East Lansing. Eastern black nightshade plants growing in the 76 cm row spacing at Clarksville were able to grow larger and produce more berries due to less competition with other eastern black nightshade plants. Eastern black nightshade at

East Lansing was not only competing with the soybean for light, moisture and nutrients, but was also competing with other nightshade plants.

Soybean population did not have a significant effect on eastern black nightshade biomass at either location. There was no significant difference in soybean canopy due to plant population, therefore, eastern black nightshade berry dry weight and biomass was not affected by soybean population. Our results are similar to those findings of other researchers. Crotser and Witt (2000) found that soybean competition greatly reduced eastern black nightshade growth. In Illinois, eastern black nightshade that emerged with the crop and grew in the open space between 76 cm rows produced 43 g dry weight and 264 berries per plant, whereas, nightshades that grew between rows spaced 33 cm apart only produced 1 g dry weight and less than 1 berry per plant (Stoller and Myers, 1989a). In Minnesota, eastern black nightshade planted in May with soybean in narrow (19 cm) rows produced 50% less berries than did plants in wide (76 cm) rows (Quackenbush and Anderson, 1984). The populations in these studies were equal in narrow versus wide rows. Our micro-plot data supports our main plot data that low populations of soybean planted in 76 cm had larger eastern black nightshade plants. The low population of soybean allowed for more eastern black nightshade growth.

Micro-plot yields

Soybean yield in the micro-plots did not increase in narrow rows compared to 76 cm rows when weeds were controlled at East Lansing. Soybean planted in 19 cm rows at 556 000 seeds/ ha had a greater yield than those planted in 76 cm rows at 432 000 seeds/ha at Clarksville. There were no differences in yield within soybean row spacing and plant population between the plots with eastern black nightshade and the weed free plots indicating that eastern black nightshade at densities of 3 to 14 plants/m^2 in August at Clarksville or 13 to 24 plants/m^2 did not reduce soybean yield.

Soybean Yield

In 2001, soybean yield at East Lansing was not greater in narrow rows compared to 76 cm rows when weeds were controlled. Rainfall was below average in July and August of 2001, therefore, soybean yield was not greater in narrow rows as expected in a normal rainfall year. Eastern black nightshade did not decrease soybean yield compared to the glyphosate treatment in 19 cm rows. However, soybean yield was reduced in 76 cm rows when planted at 432 000 seeds/ha. The addition of imazethapyr to glyphosate did not increase yield compared to glyphosate alone because no eastern black nightshade emerged after the glyphosate application.

In 2002, soybean yield at East Lansing was not greater in 19 cm rows compared to 76 cm rows, regardless of plant population. Rainfall in August was 50% below the 30 year average (Table 1). Eastern black nightshade did not reduce yield in soybean planted in 19 cm rows. However, eastern black nightshade reduced soybean yield in the untreated control compared to glyphosate alone in soybean seed in 76 cm rows at 432 000 seeds/ha. An eastern black nightshade density of 5 plants per m^2 at harvest reduced the soybean yield in this population. Furthermore, in the untreated control treatments, yield was reduced in the 76 cm seeded at 185 000 seeds/ha compared to 76 cm seeded at 432 000 seeds/ha. There were no significant differences in eastern black nightshade biomass between these two treatments at soybean harvest. Yield of soybean treated with glyphosate + imazethapyr was equal to the yield of soybean treated with glyphosate alone in 19 cm rows and in 76 cm rows at seeded populations of 185 000 and 308 000 seeds/ha.

At 432 000 seeds/ha, the soybean yield in the glyphosate treatment was greater than the yield of glyphosate + imazethapyr. This cannot be attributed to weed control or visible soybean injury, as there were no weeds present in either of these treatments after the herbicide applications were made and no visible injury to the soybean was observed after the herbicide application.

At Clarksville in 2002, soybean yield in the glyphosate only treatment in 19 cm rows at a population of 308 000 seeds/ha was greater than yield of the same population in the 76 cm rows. Eastern black nightshade decreased soybean yield in 19 cm rows at 308 000 and 556 000 seeds/ha. Eastern black nightshade also decreased soybean yield when seeded at 185 000 seeds/ha in 76 cm rows. An eastern black nightshade density of 7 plants per m^2 for soybean seeded at 185 000 seeds/ha in 76 cm rows reduced soybean yield by 10%. Eastern black nightshade densities of 4 and 2 plants per m^2 reduced yield by 14% and 6% for soybean planted in 19 cm rows at 308 000 and 556 000 seeds/ha. Glyphosate + imazethapyr reduced yield in 76 cm rows at a population of 432 000 and 19 cm rows at a population of 308 000.

In conclusion, planting soybean in 19 cm rows at populations of 308 000, 432 000, and 556 000 seeds/ha is likely to reduce the number of eastern black nightshade plants that survive and produce seed. Planting soybean in 76 cm rows at 308 000 and 432 000 seeds/ha may also reduce the survival and competiveness of eastern black nightshade. Only one application of glyphosate was needed in this study to control eastern black nightshade in both 19 cm and 76 cm rows, regardless of plant population. Nightshade that emerged in soybean planted in 19 cm row spacings were smaller and produced fewer berries compared to those that emerged in 76 cm rows, regardless of soybean population. Planting soybean at higher populations in 19 cm or 76 cm row spacing did not increase soybean yield in years of limited soil moisture. Furthermore, increased soybean population in narrow rows had no additional beneficial effect on eastern black nightshade emergence and growth. Therefore, the increased cost of soybean seed for high populations in narrow rows was not justified for decreasing eastern black nightshade emergence, growth or seed production. Seed populations of 308 000 and 432 000 in 76 cm row soybean were beneficial in reducing eastern black nightshade dry weight per plant in 1 of 3 site years. Eastern black nightshade at densities of 2 to 7 plants per m^2 reduced the yield of soybean planted at populations of 308 000 and 556 000 seeds/ha in 19 cm rows and 185 000 seeds/ha in 76 cm rows in 1 of 3 site years.

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Figures

Figure 1. Cumulative eastern black nightshade emergence at East Lansing, MI in 2001. LSD applies to total seasonal emergence at 90 days after planting.

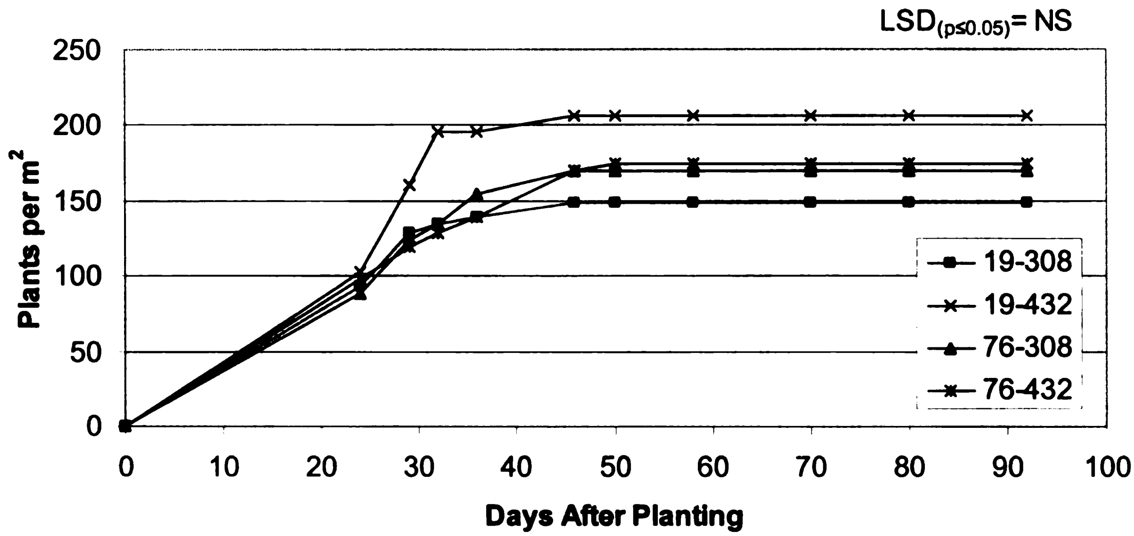

Figure 2a. Cumulative eastern black nightshade emergence at East Lansing, MI in 2002. LSD applies to total seasonal emergence at 90 days after planting.

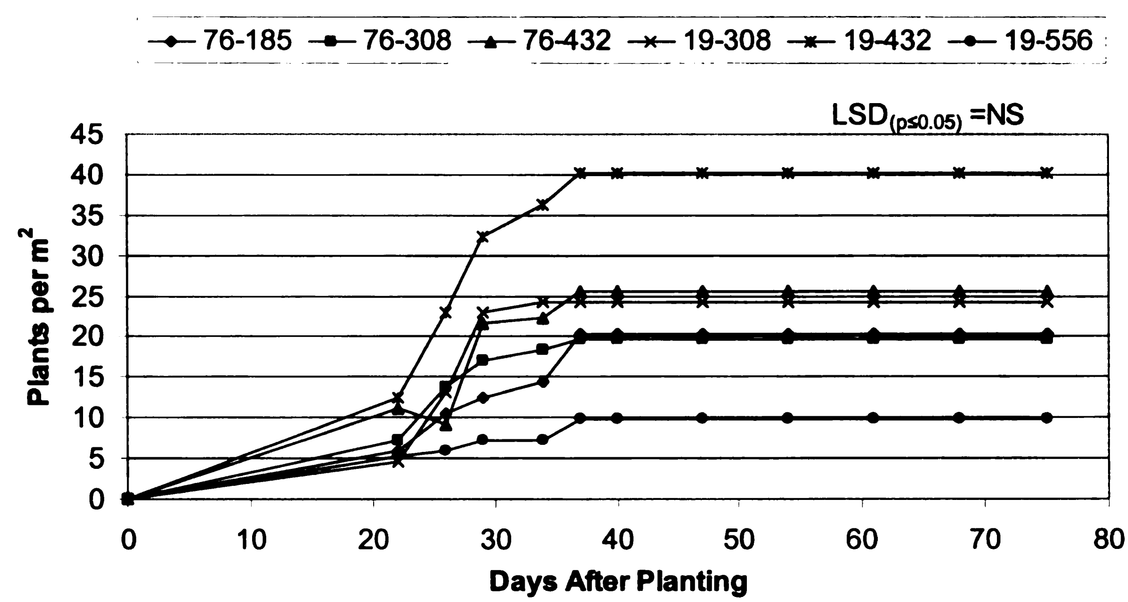

Figure 2b. Cumulative eastern black nightshade emergence at Clarksville, MI in 2002. LSD applies to total seasonal emergence at 90 days after planting.

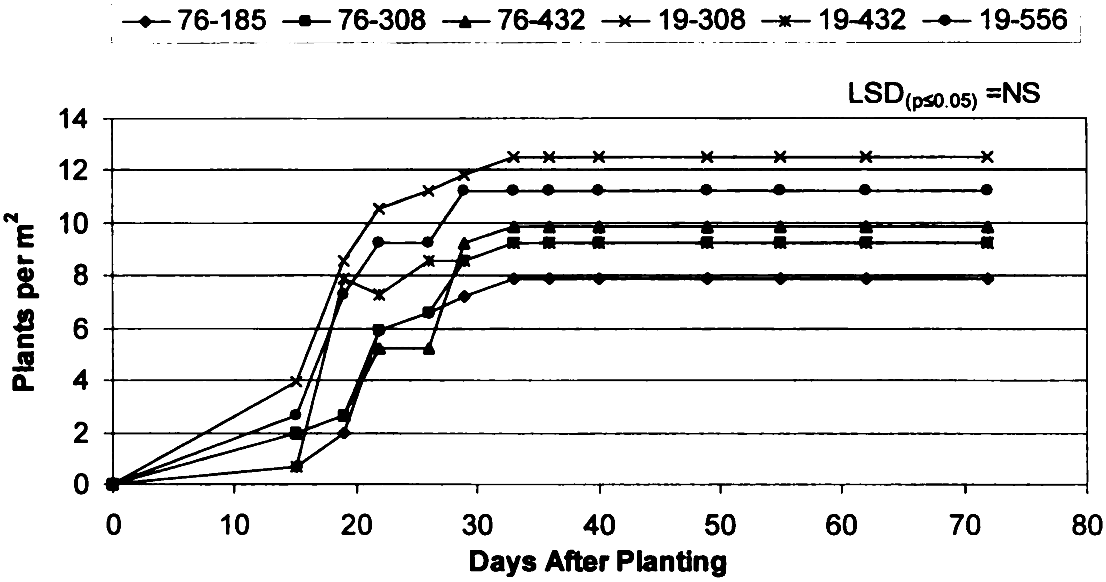

Figure 3. Soybean canopy development at East Lansing in 2001. Leaf area index (LAI) was obtained by a non-destructive measurement using the SunScan Canopy Analysis System (Delta-T Devices Ltd, Cambridge, England).

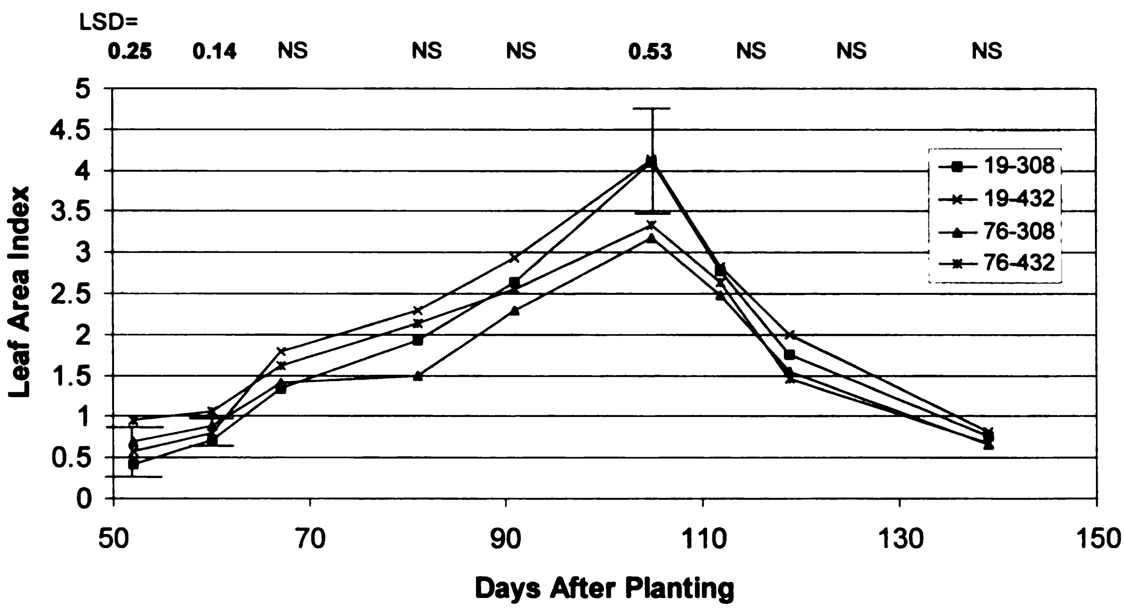

Figure 4a. Soybean canopy development at East Lansing in 2002. Leaf area index (LAI) was obtained by a non-destructive measurement using the SunScan Canopy Analysis System (Delta-T Devices Ltd, Cambridge, England).

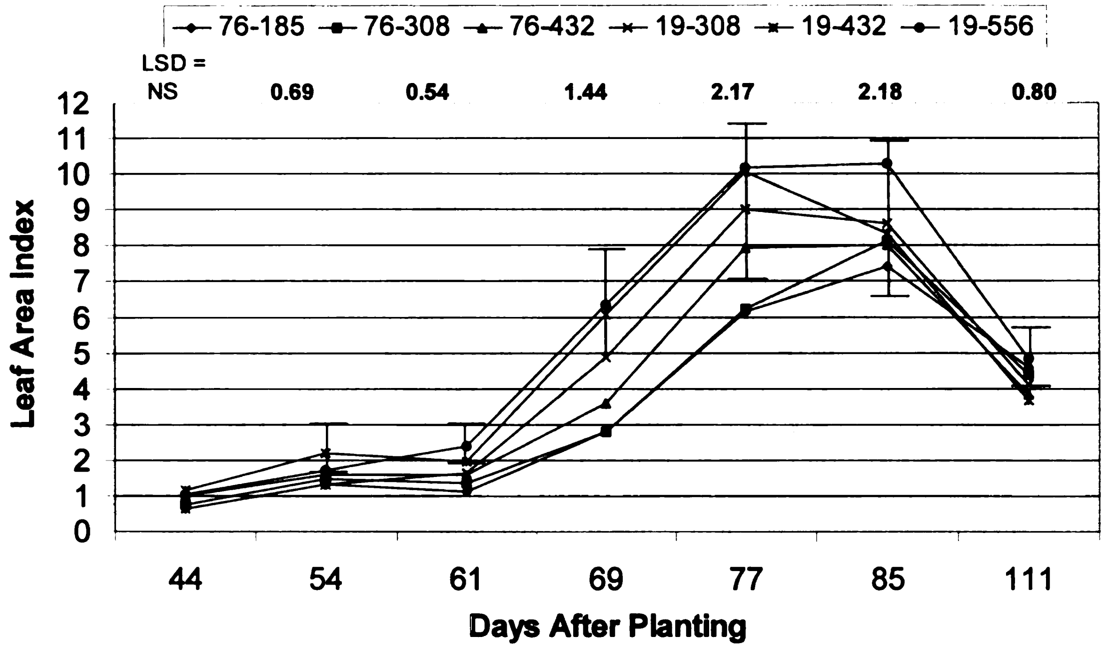

Figure 4b. Soybean canopy development at Clarksville in 2002. Leaf area index (LAI) was obtained by a non-destructive measurement using the SunScan Canopy Analysis System (Delta-T Devices Ltd, Cambridge, England).

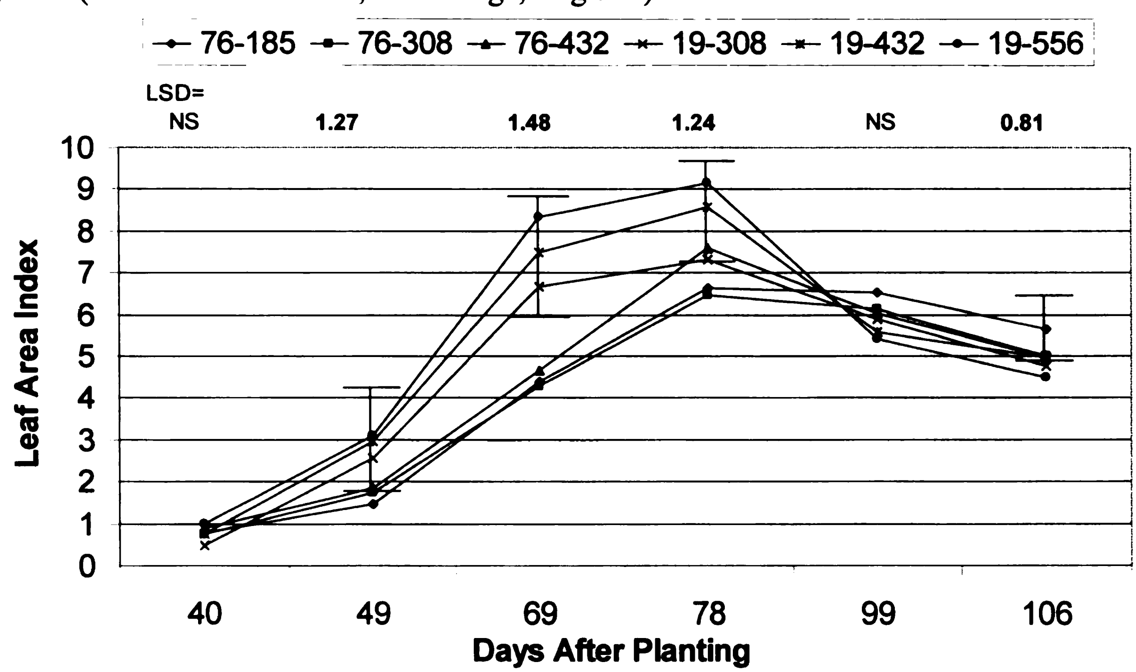

Table 1. Monthly precipitation recorded at the Michigan State University Department of Horticulture Teaching and Research Center, East Lansing, MI, and at the Clarksville Horticulture Experiment Station in Clarksville, MI.

	Precipitation (cm)				
	East Lansing			Clarksville	
	2001	2002	30 yr.	2002	30 yr
May	14.5	12.1	6.9	10.4	7.4
June	8.5	5.4	8.9	6.6	4.7
July	2.4	9.5	7.6	4.7	6.0
Aug.	4.1	3.6	7.9	7.1	9.2
Total	25.4	30.6	31.3	28.8	32.2

Table 2. Eastern black nightshade density and dry weight per plant in October 2001 at East Lansing as affected by soybean row spacing and plant population.[a]

Soybean Plant Population (seed/ha)	Eastern Black Nightshade Density (plants/m^2)	Eastern Black Nightshade Dry Weight per Plant (g)
19 cm		
308 000	38 a	1.39 a
432 000	30 a	1.11 a
76 cm		
308 000	33 a	1.92 a
432 000	35 a	1.09 a

[a]Within column values followed by different lower case letters are statistically different at $\alpha = 0.05$.

Table 3. Eastern black nightshade density and dry weight per plant at Clarksville and East Lansing as affected by soybean row spacing and plant population in October 2002.[a]

	Eastern Black Nightshade Density		Eastern Black Nightshade Dry Weight Per Plant	
	East Lansing	Clarksville	East Lansing	Clarksville
	(plants per m^2)		(g)	
19 cm				
308 000	0 b	4 ab	0 b	0.86 b
432 000	0 b	4 ab	0 b	0.69 b
556 000	0 b	2 b	0 b	0.45 b
76 cm				
185 000	4 a	7 a	1.93 a	2.21 a
308 000	4 a	4 ab	1.04 ab	1.87 ab
432 000	5 a	3 b	0.61 ab	1.24 b

[a]Within columns values followed by different lower case letters are significantly different at $\alpha = 0.05$.

Table 4a. Eastern black nightshade density in microplots at East Lansing in 2002.[a]

Soybean Plant Population (seed/ha)	Eastern Black Nightshade Density: July 9	August 6	October 1
	Plants per m^2		
19 cm			
308 000	20 ab	15 b	2 b
432 000	15 b	15 b	2 b
556 000	16 b	14 b	0 b
76 cm			
185 000	22 ab	24 a	13 a
308 000	25 a	22 a	13 a
432 000	21 ab	23 a	10 a

[a]Within columns values followed by different lower case letters are significantly different at $\alpha = 0.05$.

Table 4b. Eastern black nightshade density in microplots at Clarksville in 2002.[a]

Soybean Plant Population (seed/ha)	Eastern Black Nightshade Density		
	July 9	August 6	October 1
	Plants per m^2		
19 cm			
308 000	12 ab	3 b	12 ab
432 000	5 ab	3 b	5 b
556 000	4 b	7 ab	9 ab
76 cm			
185 000	15 a	11 ab	13 ab
308 000	15 a	10 ab	17 a
432 000	13 ab	14 a	11 ab

[a]Within columns values followed by different lower case letters are significantly different at $\alpha = 0.10$.

Table 5. 2002 eastern black nightshade dry weight per plant in microplots as affected by soybean row spacings of 19- and 76-cm.[a]

	Total dry weight		
	July 9	August 6	October 1
		g	
East Lansing			
19 cm	0.07 b	0.15 b	0.01 a
76 cm	0.19 a	0.69 a	0.51 a
Clarksville			
19 cm	0.09 b	0.17 b	0.40 b
76 cm	0.47 a	1.14 a	1.45 a

[a]Within columns values followed by different lower case letters are significantly different at $\alpha = 0.10$.

Table 6. 2002 eastern black nightshade berry dry weight in microplots as affected by soybean row spacings of 19- and 76-cm. [a]

	Berry Dry Weight	
	August 6	October 1
	g	
East Lansing		
19 cm	0.00 a	0.00 a
76 cm	0.20 a	0.29 a
Clarksville		
19 cm	0.01 a	0.12 b
76 cm	1.48 a	0.99 a

[a]Within columns values followed by different lower case letters are significantly different at $\alpha = 0.05$.

Table 7a. Effect of soybean row spacing, plant population, and eastern black nightshade on microplot soybean yield at East Lansing in 2002.[a b]

Soybean Population (seeds/ha)	Soybean Yield (kg/ha)	
	Untreated	Glyphosate
19 cm		
308 000	2441 AB(a)	2760 A(a)
432 000	2547 AB(a)	2547 A(a)
556 000	2208 B(a)	2356 A(a)
76 cm		
185 000	2675 AB(a)	2654 A(a)
308 000	2314 AB(a)	2632 A(a)
432 000	2866 A(a)	2484 A(a)

[a]Mean separation ($LSD_{0.05}$) between herbicide treatments within soybean row spacing and population are denoted by lower case letters within parentheses.

[b]Mean separation ($LSD_{0.05}$) within herbicide treatment are denoted by capital letters.

Table 7b. Effect of soybean row spacing, plant population and eastern black nightshade on microplot soybean yield at Clarksville in 2002. [a b]

Soybean Population (seeds/ha)	Soybean Yield (kg/ha) Untreated	Glyphosate
19 cm		
308 000	3267 A(a)	3028 B(a)
432 000	3249 A(a)	3285 AB(a)
556 000	3010 A(a)	3579 A(a)
76 cm		
185 000	3341 A(a)	3348 AB(a)
308 000	3029 A(a)	3568 AB(a)
432 000	3194 A(a)	2980 B(a)

[a]Mean separation ($LSD_{0.05}$) between herbicide treatments within soybean row spacing and population are denoted by lower case letters within parentheses.

[b]Mean separation ($LSD_{0.05}$) within herbicide treatment are denoted by capital letters.

Table 8. Effect of soybean row spacing, population and herbicide treatment on soybean yields at East Lansing in 2001. [a b]

	Soybean Yield (kg/ha)		
Soybean Plant Population (seeds/ha)	Untreated	Glyphosate	Glyphosate + Imazethapyr
19 cm			
308 000	3030 A(a)	3426 A(a)	3174 A(a)
432 000	3215 A(a)	3263 A(a)	3618 A(a)
76 cm			
308 000	3284 A(a)	3231 A(a)	3092 A(a)
432 000	3027 A(b)	3769 A(a)	3125 A(b)

[a]Mean separation ($LSD_{0.1}$) between herbicide treatments within soybean row spacing and population are denoted by lower case letters within parentheses.

[b]Mean separation ($LSD_{0.1}$) within herbicide treatment are denoted by capital letters.

Table 9a. Effect of soybean row spacing, population, and herbicide treatment on soybean main plot yield at East Lansing in 2002. [a b]

Soybean Population (seeds/ha)	Soybean Yield (kg/ha) Untreated	Glyphosate	Glyphosate + Imazethapyr
19 cm			
308 000	3490 A(a)	3544 A(a)	3526 A(a)
432 000	3524 A(a)	3652 A(a)	3319 A(a)
556 000	3396 AB(a)	3517 A(a)	3601 A(a)
76 cm			
185 000	3040 B(a)	3376 A(a)	3245 A(a)
308 000	3295 AB(a)	3416 A(a)	3547 A(a)
432 000	3551 A(b)	3968 A(a)	3415 A(b)

[a]Mean separation ($LSD_{0.1}$) between herbicide treatments within soybean row spacing and population are denoted by lower case letters within parentheses.

[b]Mean separation ($LSD_{0.1}$) within herbicide treatment are denoted by capital letters.

Table 9b. Effect of soybean row spacing, plant population and herbicide treatment on soybean main plot yield at Clarksville in 2002. [a b]

	Soybean Yield (kg/ha)		
Soybean Plant Population (seeds/ha)	Untreated	Glyphosate	Glyphosate + Imazethapyr
19 cm			
308 000	3228 BC(b)	3773 A(a)	3411 B(b)
432 000	3558 A(a)	3403 B(a)	3440 B(a)
556 000	3537 A(b)	3753 A(a)	3626 A(ab)
76 cm			
185 000	3120 B(b)	3450 B(a)	3299 B(ab)
308 000	3349 B(a)	3336 B(a)	3342 B(a)
432 000	3443 A(ab)	3618 A(a)	3386 B(b)

[a]Mean separation ($LSD_{0.1}$) between herbicide treatments within soybean row spacing and population are denoted by lower case letters within parentheses.

[b]Mean separation ($LSD_{0.1}$) within herbicide treatment are denoted by capital letters.

CHAPTER 3

THE INFLUENCE OF LIGHT QUANTITY AND QUALITY ON THE EMERGENCE AND GROWTH OF EASTERN BLACK NIGHTSHADE (*Solanum ptycanthum)* AND HAIRY NIGHTSHADE (*Solanum sarrachoides)*.

Abstract. Growth chamber and greenhouse experiments were conducted to determine the effect of light quantity and quality on the germination and growth of eastern black nightshade and hairy nightshade. The germination of eastern black nightshade was not significantly reduced regardless of shade level. Hairy nightshade germination was reduced by an irradiance level of 46 $\mu E/m^2/sec$ compared to 146 $\mu E/m^2/sec$. Leaf, reproductive, and total dry weight of eastern black nightshade and hairy nightshade was reduced in light levels of 63 $\mu E/m^2/sec$ compared to full greenhouse light. Eastern black nightshade and hairy nightshade had similar leaf areas in full greenhouse light, however, eastern black nightshade leaf area did not decrease as the available irradiance decreased. Both hairy and eastern black nightshade adapt to a shaded environment by producing thinner leaves and increasing their leaf surface area. The leaf, reproductive and total dry weight of both nightshade species was greater under full greenhouse light compared to plants grown under neutral and reduced red: far red shade treatments. The specific leaf area of eastern black nightshade and hairy nightshade was greater under the neutral density shading compared to full greenhouse light and reduced R: FR treatments, indicating a blue-absorbing pigment response. Eastern black and hairy nightshade growth and reproduction were reduced when grown under irradiances of 63 and 51 $\mu E/m^2/sec$, indicating that narrowing soybean row spacing and increasing plant population will also reduce the growth and reproduction of these shade tolerant species.

KEY WORDS: Light quality, light quantity, eastern black nightshade (*Solanum ptycanthum*), hairy nightshade (*Solanum sarrachoides*).

INTRODUCTION

Shade effectively inhibits the growth of many weeds because of the reduction in irradiance. Crops and weeds show varying degrees of shade tolerance. Eastern black nightshade, tumble pigweed, and common cocklebur were photosynthetically efficient under low-growth irradiance due to a combination of physiological and morphological adaptations (Holt, 1995; Regnier et al, 1988; Stoller and Myers, 1989). Hairy nightshade, another nightshade species that is common in Michigan, did not persist in dense shades (Tan and Weaver, 1997). Increased leaf area ratio (LAR) and plant height are common responses to shade that may offset reductions in photosynthetic rate and biomass production that commonly occur. However, seed production is generally reduced when reductions in light are extreme (Holt, 1995). Eastern black nightshade can be a problem in soybean fields because seedlings can emerge from sites receiving full sunlight between soybean rows, and they can also emerge from heavily shaded sites beneath the soybean canopy. Furthermore, eastern black nightshade can grow under the soybean canopy where irradiance levels are less than 100 $\mu E/m^2/s$ (Stoller and Myers, 1989a). Nightshade growth and berry production are greatly reduced once the soybean canopy begins to close, but the ability of eastern black nightshade to survive beneath a soybean canopy creates the potential for eastern black nightshade to be problematic throughout the growing season.

Sporadic seed germination is a common trait in black nightshade, which enables nightshade seedlings to emerge throughout the growing season (Keely and Thullen, 1983). Nightshade began to germinate in the spring and emergence continued throughout the summer when adequate moisture was available in Washington, Canada, and England (Ogg and Dawson, 1984; Roberts and Boddrell, 1983; Basset and Munro, 1985; Roberts and Lockett, 1978). Roberts and Lockett reported that black nightshade seeds failed to germinate at constant temperatures in the range of 4-30°C; however, with alternating temperatures of 10/25, 10/30, 15/25 and 15/30 the percent germination was high (Roberts and Lockett, 1978). The most rapid and complete germination occurred when the upper temperature was 25 to 30°C. Hairy and eastern black nightshade seeds germinated in the field when soil temperatures were between 20° and 46° C. The optimum temperature for germination of eastern black nightshade and hairy nightshade was 30° C (Bugert et al, 1973).

The presence of a leaf canopy alters the quantity as well as the spectral distribution, or quality, of light underneath it. Leaves absorb light in the blue and red regions and reflect or transmit in the green and far red regions of the spectrum. With increasing depth in a plant canopy, light is enriched in the far red wavelengths and has a lower red:far red ratio (Smith, 1994). The morphological responses seen by plants in response to reduced irradiance, such as increased leaf area ratio (LAR), are triggered by phytochrome in response to the low red: far red ratios under plant canopies (Taiz and Zieger,2002). These morphological responses include stem elongation, flowering, and changes in stomatal conductance or plant anatomy. Leaf thinning in shaded conditions has also been attributed to an increase in the ratio of R: FR light, but may also result from a decrease of blue light.

Weed success depends on survival and some level of reproduction to continue the species. Knowledge of the responses of hairy nightshade and eastern black nightshade to different levels of light quantity and quality will allow for the development of management techniques to enhance control of these two weed species. The objectives of this experiment were to determine the effect of light quantity and quality on the germination and growth of eastern black nightshade and hairy nightshade. We hypothesize that shading will have no effect on the germination of either nightshade species. Secondly, we hypothesize that eastern black nightshade will have greater biomass and leaf area compared to hairy nightshade when grown under neutral shade levels of 30%, 60%, and 90%; however both species of nightshade will have optimum biomass and leaf area when light interception is not reduced. Furthermore, we hypothesize that reduced red: far red light will result in greater leaf area of nightshade species compared to leaf area neutral light.

MATERIALS AND METHODS

The effect of neutral density shading on germination of eastern black nightshade and hairy nightshade.

Seed was collected in the fall of 2000 from a population of hairy nightshade and eastern black nightshade growing in farmer's fields in Michigan. Hairy nightshade was collected in Presque Isle Country and eastern black nightshade berries were collected in Ingham County. Berries were air dried and seed removed by crushing the berries. Seed was then separated from the inert matter by sieving. The seeds were washed with water to remove any seed inhibitors and air dried on aluminum foil. Preliminary germination studies were conducted. Twenty-five seeds of eastern black nightshade and hairy nightshade were placed in a seed germinator at varying alternating temperatures of 20:10, 25:15, 25:25, 30:20, and 35:25 degrees C. It was shown that the optimum temperature for germination of both species was 30:20 C with a 14 hr photoperiod. These results are similar to that found previously in the literature (Bugert et al. 1973, Givelberg and Horowitz 1984, Roberts and Lockett 1978, and Thomson and Witt 1987). Sixteen pots were seeded with each species of nightshade. Twenty nightshade seeds were placed at a 1 cm depth in the soil in each pot. The soil used was a Spinks loamy sand (sandy mixed, mesic Psammentic Hapludalfs) with a pH of 6.8 and 2.4% organic matter. The seed was evenly distributed throughout the pot and the pots were placed in the growth chamber under 30°: 20°C with 14 hour daylight. Dark shade cloth rated for solar radiation interception of approximately 30%, 60%, and 90% was placed over four pots of each species at planting. Irradiance levels beneath this cloth was of 146, 46 and 32 $\mu E/m^2/sec$, denoting an actual 42%, 82%, and 87% reduction in light quantity. The other four pots of each species were the control with no shade cloth with an irradiance level of 255

$\mu E/m^2/sec$. Photosynthetic photon flux density (PPFD) was measured for each light level using a recently calibrated LI-COR LI-185B[1] quantum sensor. Shade structures were arranged to minimize any shading of one particular treatment by another. Pots were watered each day as needed and pots were evaluated every three days for nightshade emergence. Nightshade was clipped at the soil line at the cotyledon stage to prohibit potential shading of the soil. Pots were rotated within shade level weekly. The experiment was terminated after 3 weeks and repeated. The experiment was a two factor factorial with nightshade species as one factor and light level as the second factor and was arranged in a completely randomized design with four replications. An analysis of variance was conducted using PROC GLM in SAS and experiments were combined over time. Means were separated with Fisher's LSD at the 5% level.

The effect of light quality and quantity on the growth of eastern black nightshade and hairy nightshade.

Thirty pots were seeded with pre-germinated eastern black nightshade and hairy nightshade seed. Five pre-germinated seeds were placed at a 1 cm depth in the soil in each pot. Pots were placed in the greenhouse under 27 ± 5 degrees Celsius and 14 hr of natural daylight supplemented by sodium vapor lighting with a PPFD of 120 $\mu E\ m^{-2} \cdot s^{-1}$. Dark shade cloth rated for solar radiation interception of approximately 30%, 60%, and 90%, and shade cloth with reduced red:far red light with a radiation interception similar to the 60% dark shade was placed over six pots of each species at planting. The other six pots of each species were the control with no shade cloth. Irradiance levels corresponded to 195, 63 and 51 $\mu E/m^2/sec$ for the dark shade cloth, 68 $\mu E/m^2/sec$ for the reduced red: far red shade, and 292 $\mu E/m^2/sec$ for the control, denoting a 33%, 78%, 82%, and 77%

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[1] LI-COR, 4421 Superior Street, P.O. Box 4425, Lincoln, NE 68504.

actual reduction in light quantity. PPFD was measured at approximately solar noon on a clear day within each shade level using a recently calibrated LI-COR LI-185B[1] quantum sensor. Spectral emission beneath each shade level over the range of 300 to 1100 nm was determined using a LI-COR 1800[1] portable spectral radiometer. The amount of red: far red light was then calculated by the following formula as described by Kendrick and Kronenberg (1994) :

$$R: FR = \frac{\text{Photon irradiance between 655 and 665 nm}}{\text{Photon irradiance between 725 and 735 nm}}$$

Shade structures were 2.5 feet tall and 1.5 feet wide and arranged to minimize any shading of one particular treatment by another. Pots were watered each day as needed and fertilized with 3 g of water soluble fertilizer (20% N, 20% P_2O_2, and 20% K_2O) per gallon of water and pots were re-randomized on a weekly basis under each shade treatment. Nightshade was thinned to one plant per pot when the plants were at the six leaf stage. The plants were evaluated bi-weekly beginning 14 d after planting by recording the growth stage of each plant in each pot. Leaf area, fresh weight and dry weight of leaves and total biomass were measured destructively 8 weeks after planting. Specific leaf area (SLA) was calculated by dividing leaf area by leaf dry weight (Kvert et al. 1971). Leaf area was measured using a LI-COR LI 3000[1] portable area meter. The experiment was a two-factor factorial with nightshade species as one factor and light level as the second factor arranged in a completely randomized design with four replications and repeated. An analysis of variance was conducted using PROC GLM in SAS and experiments were combined over time. Means were separated with Fisher's LSD at the 5% level.

RESULTS AND DISCUSSION

The effect of neutral density shading on germination of eastern black nightshade and hairy nightshade.

The maximum emergence of eastern black nightshade and hairy nightshade was 20% and 34%, respectively (Table 1). Thompson and Witt (1987) reported 72% germination of eastern black nightshade under similar conditions. It has been reported that germination of dry stored nightshade seeds is promoted by gibberellic acid (Basset and Munro 1985, Givelberg and Horowitz 1984, and Roberts and Lockett 1978). Dormant seeds of hairy nightshade germinated 50% or more after soaking for 12 h in 2.8 x 10^{-6} M gibberellic acid and incubating for several days at 20/30 C (Givelberg and Horowitz 1984). The nightshade seed in this study was not treated with gibberellic acid, which may account for the low percentage of germination.

The germination of eastern black nightshade was not significantly reduced, regardless of shade level (Table 1). However, hairy nightshade germination was reduced by an irradiance level of 46 $\mu E/m^2/sec$ compared to the 146 $\mu E/m^2/sec$ ($p = 0.0018$). When both species were compared within a shade treatment, hairy nightshade had significantly greater emergence in 146 $\mu E/m^2/sec$ ($p = .0032$) and 46 $\mu E/m^2/sec$ ($p = 0.0430$) shade treatments compared to eastern black nightshade. These results imply that our seed source of hairy nightshade had greater germination at two of four shade levels compared to eastern black nightshade, and that our dry storage conditions were not conducive for germination. Furtherore, this seed source of hairy nightshade had decreased seed germination under conditions of low irradiance. Seed germination can be influenced by the environment at the time of seed formation by seed position on the plant and by post harvest seed handling (Rogers and Ogg 1989). It would be of interest to compare seeds from the same field to determine if hairy nightshade germination is reduced in low irradiance.

The effect of light quality and quantity on the growth of eastern black nightshade and hairy nightshade.

Light Quantity

Leaf (p = <.0001), reproductive (p =<.0001) and total dry weight (p =<.0001) of eastern black nightshade and hairy nightshade was significantly reduced in light levels of 63 $\mu E/m^2/sec$ and 51 $\mu E/m^2/sec$ compared to full greenhouse light (Table 2). Hairy nightshade reproductive dry weight was also reduced (p=.007) by an irradiance of 195 $\mu E/m^2/sec$ compared to full greenhouse light. The leaf area of eastern black nightshade was greater than the leaf area of hairy nightshade at all reduced irradiance levels, but not under full greenhouse light. Furthermore, the leaf area of hairy nightshade, but not eastern black nightshade, was reduced at an irradiance of 51 $\mu E/m^2/sec$ (p = .0042) compared to full greenhouse light. These results indicate that eastern black nightshade and hairy nightshade have similar leaf areas at 292 $\mu E/m^2/sec$ and that eastern black nightshade leaf area did not decrease as the available irradiance decreased. Stoller and Myers (1989a) reported that eastern black nightshade had the highest leaf area ratio (LAR) compared to three other weed species tested in shaded conditions.

Eastern black nightshade and hairy nightshade had greater specific leaf area (SLA) under irradiances of 63 and 51 $\mu E/m^2/sec$ when compared to plants grown in full greenhouse light or beneath an irradiance of 195 $\mu E/m^2/sec$. The greater SLA of plants grown under shade shows a common adaptation of shade-avoiding plants, namely thinner leaves. Other research supports greater SLA for shade-intolerant weeds grown under neutrally filtered radiation (Regnier and Harrison 1993; Crotser and Witt 2003), indicating that the thinner leaves optimize leaf surface area and chlorophyll exposure to light. Blackshaw (1991) reported that hairy nightshade does not persist in dense shade, although it is able to compete for light in widely spaced row crops. Our data suggest that hairy nightshade is also able to adapt to a shaded environment by producing thinner leaves and increasing the leaf surface area to optimize the available light.

Light Quality

The leaf, reproductive, and total dry weight of both nightshade species was greater in the no shade treatment compared to plants grown under both neutral and reduced R: FR shade treatments. Additionally, the leaf and total dry weight of both nightshade species grown under reduced red: far red (R: FR) shade with a light quantity of 68 $\mu E/m^2/sec$ was greater than the leaf dry weight of plants grown under neutral density shade with a light quantity of 63 $\mu E/m^2/sec$ (Table 3). Although the plant weights were greater in the no shade treatment, the leaf area of eastern black nightshade was greater beneath the reduced R: FR shade compared to neutral density shade and full sun. The leaf area of hairy nightshade was greater in the no shade compared to the neutral density treatment. When the SLA was calculated, the SLA of eastern black nightshade and hairy nightshade was greater under the neutral density shading. A possible explanation for this could be that the response of thinner leaves seen in nightshade plants grown under neutral density shade was caused by blue-absorbing pigments instead of phytochrome. Brits and Sager (1990), reported that at equal PPFD, soybean and sorghum (*Sorghum bicolor* L.) leaves were thinner when plants were grown under blue deficient lamps (low pressure sodium) when compared with broad-spectrum daylight fluorescent lamps. This suggests that reduced irradiance, specifically blue light, inhibited the development of thick leaves in eastern black nightshade and hairy nightshade, since thinner leaves occurred only at neutral shade density and not in the reduced R: FR shade treatment.

Red to far red ratios were measured as 1.11, 1.07, and 0.98 for plants grown under full sun, neutral, and reduced R: FR shade, respectively. In full sunlight, there is a R: FR ratio of approximately 1.10 and a soybean canopy will typically have a R: FR ratio of 0.14 (Smith, 1994). Therefore, although the red to far red ratio was reduced somewhat with the green shade cloth, the reduction in R: FR light was minimal for our study. Consequently, the differences in growth between the two shade treatments may be explained by differences in the microclimate beneath the two shade treatments. Although both the neutral density cloth and the reduced R: FR cloth were rated for 60% shade, the reduced R: FR cloth allowed 1.7% more light (68 $\mu E/m^2/sec$) to be available for plant growth compared to the neutral density cloth (63 $\mu E/m^2/sec$). Therefore, irradiance was increased very slightly under the green compared to the black shade cloth treatment. Of more importance was the daily maximum temperature beneath the shade structures. The daily temperature maximums beneath the reduced R: FR shade cloth was approximately 5° C warmer than that of the neutral density shading on days with full sun (Figure 1). On cloudy days, the temperature was similar between both shade treatments, although still slightly elevated under the reduced R: FR compared to the neutral shade. The increase in temperature in the green shade cloth allowed the nightshade plants under the reduced R: FR cloth to produce more biomass than those growing beneath the neutral density shade.

In conclusion, the leaf, reproductive, and total dry weight of eastern black nightshade and hairy nightshade decreased as light quantity and the ratio of red to far-red light decreased. Under natural conditions, full sunlight would have an irradiance level of approximately 2000 $\mu E/m^2/sec$. Full light in the greenhouse conditions in this study measured 292 $\mu E/m^2/sec$. This is a shaded environment in comparison to field conditions; therefore, plants grown in the full greenhouse light treatment may have also shown some effects due to shading.

The leaf area of eastern black nightshade was only reduced under neutral density shading at an irradiance of 32 $\mu E/m^2/sec$. The leaf area of hairy nightshade was reduced under both neutral and reduced R: FR light with irradiances of 63 and 68 $\mu E/m^2/sec$, respectively. Reproductive dry weight for eastern black nightshade and hairy nightshade was reduced by 89% when light quantity was reduced by 82% compared to full greenhouse light. The SLA of eastern black nightshade and hairy nightshade was greatest under irradiances of 63 and 51 $\mu E/m^2/sec$ beneath neutral density shade compared to that of reduced R: FR shade and full greenhouse light, indicating a blue pigment response.

The growth and reproduction of both hairy nightshade and eastern black nightshade decreased when grown in shade. The compensatory responses of eastern black nightshade to shade, by maximizing interception of available light, allows eastern black nightshade to maintain growth under shaded conditions. However, eastern black nightshade growth and reproduction were reduced when grown under irradiances of 63 and 51 $\mu E/m^2/sec$, indicating that narrowing soybean row spacing and increasing plant population will also reduce the growth and reproduction of this shade tolerant species. Hairy nightshade is also able to adapt to a shaded environment by producing thinner leaves and increasing the leaf surface area to optimize the available light, allowing it to be more competitive in wide spaced crops. However, at high levels of shade, hairy nightshade growth and reproduction is also reduced, indicating that narrowing crop rows and increasing plant population will also reduced the growth and reproduction of hairy nightshade.

Table 1. Effect of neutral shading on the cumulative emergence of eastern black nightshade and hairy nightshade.[a]

Light Quantity $\mu E/m^2/sec$	Eastern Black Nightshade	Hairy Nightshade
	— Number Emerged out of 20 seeds —	
32	3.2 c	4.4 bc
46	3.8 c	6.3 ab
146	4.7 bc	8.4 a
255	5.0 bc	6.7 ab

[a]Treatment means within a column followed by the same letter are not statistically different at the 5% level.

[b]Treatment means within a row followed by the same letter are not statistically different at the 5% level.

Table 2. Effects of neutral shading on the reproductive, stem, leaf, and total dry weight, leaf area, and specific leaf area of eastern black nightshade and hairy nightshade[a].

Light Quantity $\mu E/m^2/sec$	Leaf Dry Weight	Reproductive Dry Weight	Total Dry Weight	Leaf Area	Specific Leaf Area*
	g			cm^2	$cm\ g^{-1}$
Eastern Black Nightshade					
51	0.60 cd	0.03 c	0.93 b	690.08 bc	1190.60 a
63	1.15 c	0.09 c	1.65 b	867.75 ab	937.62 a
195	2.75 ab	0.71 ab	4.88 a	1001.75 a	394.54 b
292	2.96 a	1.04 a	5.63 a	821.67 ab	309.04 b
Hairy Nightshade					
51	0.27 d	0.00 c	0.44 b	248.00 d	943.77 a
63	0.62 cd	0.01 c	0.97 b	459.33 cd	921.32 a
195	2.23 b	0.43 b	4.26 a	775.25 bc	367.52 b
292	2.52 ab	0.90 a	5.46 a	713.5 bc	305.28 b

[a]Treatment means within a column and followed by the same letter are not significantly different at the 5% level.

*Specific leaf area was calculated by dividing leaf area by leaf dry weight.

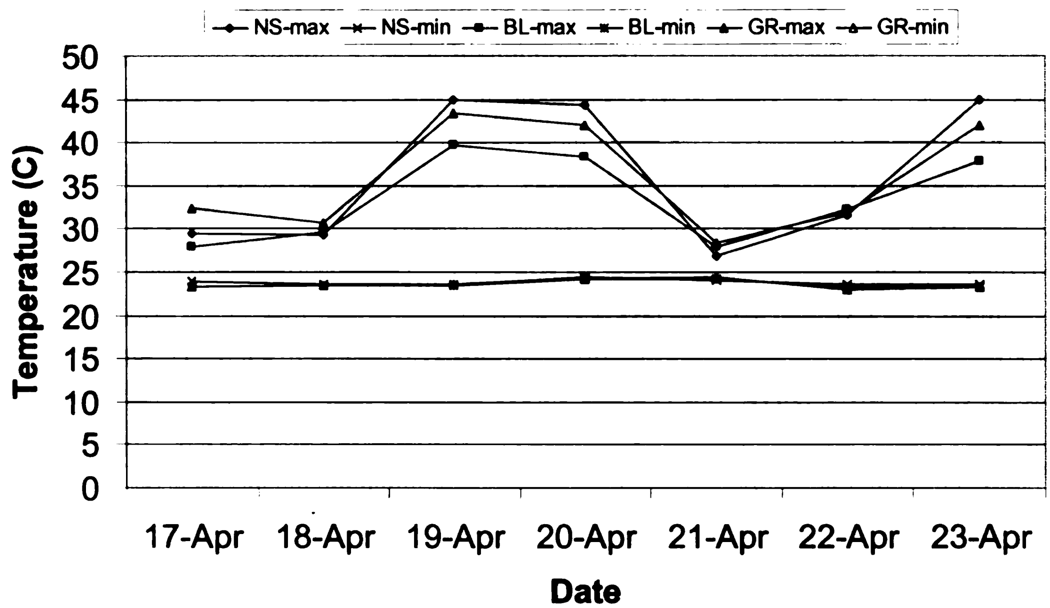
Table 3. Comparison of radiation quality on the reproductive, stem, leaf, total dry weight, leaf area and specific leaf area of eastern black nightshade and hairy nightshade.

Shade Treatment	Leaf Dry Weight[a]	Reproductive Dry Weight[a]	Total Dry Weight[a]	Leaf Area[a]	Specific Leaf Area*
	g			cm^2	$cm\ g^{-1}$
Eastern Black Nightshade					
No Shade	1.70 a	0.46 a	4.23 a	962.27 b	709.48 bc
Neutral density	0.17 c	0.01 b	0.60 c	393.38 d	2364.59 a
Reduced R: FR	1.09 b	0.11 b	3.13 a	1254.89 a	1191.98 bc
Hairy Nightshade					
No Shade	1.78 a	0.18 a	3.92 a	794.36 bc	509.16 c
Neutral Density	0.11 c	0.01 b	0.32 c	145.23 d	1371.31 b
Reduced R: FR	0.76 b	0.01 b	1.80 b	677.65 c	893.09 bc

[a]Treatment means within a column and followed by the same letter are not significantly different at the 5% level.

*Specific leaf area was calculated by dividing leaf area by leaf dry weight.

Figure 1. Temperature differences in greenhouse due to shade treatment. Daily maximum (max) and minimum (min) temperatures for no shade (NS), neutral density (BL) and reduced red: far red (GR) shade.



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APPENDICES

CHAPTER TWO ANOVA TABLES

Figure 1. Cumulative emergence of eastern black nightshade at East Lansing 2001.

Effect	Num DF	Den DF	F Value	P Value
Blk	3	3	0.95	0.5149
Row	1	3	0.02	0.9005
Pop	1	6	0.35	0.5774
Row*Pop	1	6	0.25	0.6360

Figure 2. Cumulative emergence of eastern black nightshade at East Lansing in 2002.

Effect	Num DF	Den DF	F Value	P Value
Blk	1	3	0.22	0.6692
Row	2	12	1.38	0.2889
Pop	3	3	1.16	0.4517
Row*Pop	2	12	3.0	0.0879

Figure 2b. Cumulative emergence eastern black nightshade at Clarksville 2002.

Effect	Num DF	Den DF	F Value	P Value
Row	1	3	0.51	0.5261
Pop	2	12	0.11	0.8966
Blk	3	3	2.40	0.2457
Row*Pop	2	12	0.33	0.7249

Figure 3. Soybean Canopy Development at East Lansing 2001.

52 DAP

Effect	Num DF	Den DF	F Value	P Value
Blk	3	3	0.01	0.9980
Row	1	3	10.71	0.0467
Pop	1	20	6.26	0.0211
Row*Pop	1	20	.39	0.5370

60 DAP

Effect	Num DF	Den DF	F Value	P Value
Blk	3	3	2.25	0.2611
Row	1	3	13.80	0.0339
Pop	1	54	5.87	0.0188
Row*Pop	1	54	0.65	0.4230

67 DAP

Effect	Num DF	Den DF	F Value	P Value
Blk	3	3	0.28	0.8372
Row	1	3	0.02	0.9082
Pop	1	11	7.11	0.0219
Row*Pop	1	11	1.09	0.3188

81 DAP

Effect	Num DF	Den DF	F Value	P Value
Blk	3	2	1.29	0.4651
Row	1	2	0.22	0.6857

Pop	1	5	4.03	0.1011
Row*Pop	1	5	0.27	0.6235

91 DAP

Effect	Num DF	Den DF	F Value	P Value
Blk	3	3	0.59	0.6617
Row	1	3	0.87	0.4206
Pop	1	54	1.26	0.2657
Row*Pop	1	54	0.01	0.9298

105 DAP

Effect	Num DF	Den DF	F Value	P Value
Blk	3	3	2.88	0.2042
Row	1	3	15.87	0.0283
Pop	1	54	0.29	0.5923
Row*Pop	1	54	0.09	0.7630

112 DAP

Effect	Num DF	Den DF	F Value	P Value
Blk	3	3	0.69	0.6148
Row	1	3	0.70	0.4648
Pop	1	54	0.45	0.5064
Row*Pop	1	54	0.13	0.7227

119 DAP

Effect	Num DF	Den DF	F Value	P Value
Blk	3	3	0.66	0.6281

Row	1	3	3.57	0.1554
Pop	1	54	0.43	0.5150
Row*Pop	1	54	1.65	0.2038

139 DAP

Effect	Num DF	Den DF	F Value	P Value
Blk	3	3	0.76	0.5872
Row	1	3	1.97	0.2551
Pop	1	54	0.47	0.4982
Row*Pop	1	54	0.20	0.6554

Figure 4a. Soybean Canopy Development at East Lansing 2002.

44 DAP

Effect	Num DF	Den DF	F Value	P Value
Blk	3	15	0.01	0.9986
Row	1	15	0.04	0.8372
Pop	3	15	4.54	0.0186
Row*Pop	1	15	1.57	0.2290

54 DAP

Effect	Num DF	Den DF	F Value	P Value
Blk	3	6	0.57	0.6576
Row	1	6	0.68	0.4400
Pop	3	6	3.0	0.1172
Row*Pop	1	6	1.82	0.2261

61 DAP

Effect	Num DF	Den DF	F Value	P Value
Blk	3	15	0.43	0.7337
Row	1	15	3.0	0.1037
Pop	3	15	4.11	0.0259
Row*Pop	1	15	0.12	0.7338

69 DAP

Effect	Num DF	Den DF	F Value	P Value
Blk	3	15	0.07	0.9752
Row	1	15	22.43	0.0003
Pop	3	15	2.41	0.1076
Row*Pop	1	15	0.15	0.7002

77 DAP

Effect	Num DF	Den DF	F Value	P Value
Blk	3	15	1.49	0.2564
Row	1	15	11.56	0.0040
Pop	3	15	1.75	0.1998
Row*Pop	1	15	0.24	0.6342

85 DAP

Effect	Num DF	Den DF	F Value	P Value
Blk	3	15	0.90	0.4653
Row	1	15	0.30	0.5890
Pop	3	15	1.60	0.2320

Row*Pop	1	15	0.01	0.9189

111 DAP

Effect	Num DF	Den DF	F Value	P Value
Blk	3	14	2.33	0.1181
Row	1	14	1.17	0.2973
Pop	3	14	5.22	0.0126
Row*Pop	1	14	0.18	0.6742

Figure 4b. Soybean Canopy Development at Clarksville 2002.

40 DAP

Effect	Num DF	Den DF	F Value	P Value
Blk	3	14	0.63	0.6072
Row	1	14	1.34	0.2661
Pop	3	14	1.51	0.2547
Row*Pop	1	14	0.09	0.7651

49 DAP

Effect	Num DF	Den DF	F Value	P Value
Blk	2	4	0.56	0.6097
Row	1	4	10.28	0.0327
Pop	3	4	0.75	0.5748
Row*Pop	1	4	0.16	0.7069

69 DAP

Effect	Num DF	Den DF	F Value	P Value
Blk	3	15	0.81	0.5083

Row	1	15	28.15	<0.0001
Pop	3	15	2.02	0.1537
Row*Pop	1	15	0.23	0.6365

78 DAP

Effect	Num DF	Den DF	F Value	P Value
Blk	3	15	1.96	0.1638
Row	1	15	5.02	0.0406
Pop	3	15	4.90	0.0143
Row*Pop	1	15	0.01	0.9052

99 DAP

Effect	Num DF	Den DF	F Value	P Value
Blk	3	15	1.11	0.3771
Row	1	15	0.59	0.4535
Pop	3	15	0.40	0.7581
Row*Pop	1	15	0.05	0.8289

106 DAP

Effect	Num DF	Den DF	F Value	P Value
Blk	3	15	2.13	0.1394
Row	1	15	0.26	0.6163
Pop	3	15	1.76	0.1973
Row*Pop	1	15	0.18	0.6814

Table 2. Eastern black nightshade density and dry weight per plant at East Lansing in October 2001.

Density

Effect	Num DF	Den DF	F Value	P Value
Blk	3	3	1.32	0.1394
Row	1	3	0.00	1.000
Pop	1	6	0.26	0.6265
Row*Pop	1	6	0.67	0.4435

Dry Weight Per Plant

Effect	Num DF	Den DF	F Value	P Value
Blk	3	3	1.52	0.3701
Row	1	3	0.00	0.9534
Pop	1	6	1.86	0.2218
Row*Pop	1	6	0.00	0.9869

Table 3. Eastern black nightshade density and dry weight per plant at East Lansing and Clarksville in October 2002.

East Lansing Density

Effect	Num DF	Den DF	F Value	P Value
Blk	3	3	1.00	0.5000
Row	1	3	12.45	0.0387
Pop	2	12	0.38	0.6907
Row*Pop	2	12	0.38	0.6907

East Lansing Dry Weight Per Plant

Effect	Num DF	Den DF	F Value	P Value
Blk	3	3	1.00	0.5000
Row	1	3	6.55	0.0833
Pop	2	12	2.09	0.1659
Row*Pop	2	12	2.09	0.1659

Clarksville Density

Effect	Num DF	Den DF	F Value	P Value
Blk	3	3	0.36	0.7905
Row	1	3	2.58	0.2064
Pop	2	12	3.14	0.0800
Row*Pop	2	12	0.91	0.4283

Clarksville Dry Weight Per Plant

Effect	Num DF	Den DF	F Value	P Value
Blk	3	3	1.32	0.4130
Row	1	3	10.64	0.0471
Pop	2	12	9.06	0.0040
Row*Pop	2	12	1.51	0.2600

Table 4a. Eastern black nightshade density in microplots at East Lansing in 2002.

July Density

Effect	Num DF	Den DF	F Value	P Value
Blk	3	3	0.52	0.6954
Row	1	3	2.80	0.1931

Pop	1	6	2.14	0.1938
Row*Pop	1	6	0.04	0.8413

August Density

Effect	Num DF	Den DF	F Value	P Value
Blk	3	3	1.27	0.4235
Row	1	3	5.14	0.1081
Pop	1	6	0.00	1.0000
Row*Pop	1	6	0.19	0.6754

October Density

Effect	Num DF	Den DF	F Value	P Value
Blk	3	3	2.38	0.2470
Row	1	3	22.15	0.0181
Pop	2	12	1.68	0.2280
Row*Pop	2	12	0.09	0.9161

Table 4b. Eastern black nightshade density in Microplots at Clarksville in 2002.

July Density

Effect	Num DF	Den DF	F Value	P Value
Blk	3	3	1.27	0.4255
Row	1	3	1.22	0.3508
Pop	1	6	0.93	0.3720
Row*Pop	1	6	0.17	0.6937

August Density

Effect	Num DF	Den DF	F Value	P Value
Blk	3	3	0.12	0.9419
Row	1	3	5.57	0.0994
Pop	1	6	1.17	0.3202
Row*Pop	1	6	1.17	0.3202

October Density

Effect	Num DF	Den DF	F Value	P Value
Blk	3	3	0.42	0.7520
Row	1	3	1.88	0.2636
Pop	2	12	0.53	0.6013
Row*Pop	2	12	2.03	0.1739

Table 5. 2002 eastern black nightshade dry weight per plant in Microplots as affected by soybean row spacings of 19- and 76-cm.

July at East Lansing

Effect	Num DF	Den DF	F Value	P Value
Blk	3	3	0.29	0.8332
Row	1	3	7.43	0.0722
Pop	2	12	0.28	0.7574
Row*Pop	2	12	2.64	0.1123

August at East Lansing

Effect	Num DF	Den DF	F Value	P Value
Blk	3	3	0.69	0.6155

Row	1	3	5.88	0.0938
Pop	2	12	0.33	0.7220
Row*Pop	2	12	0.03	0.9742

October at East Lansing

Effect	Num DF	Den DF	F Value	P Value
Blk	3	3	0.94	0.5201
Row	1	3	5.37	0.1033
Pop	2	12	1.53	0.2552
Row*Pop	2	12	1.97	0.1823

July at Clarksville

Effect	Num DF	Den DF	F Value	P Value
Blk	3	3	0.74	0.5952
Row	1	3	10.11	0.0501
Pop	2	12	1.69	0.2254
Row*Pop	2	12	0.15	0.8656

August at Clarksville

Effect	Num DF	Den DF	F Value	P Value
Blk	3	3	1.06	0.4821
Row	1	3	14.91	0.0307
Pop	2	12	0.17	0.8452
Row*Pop	2	12	0.14	0.8726

October at Clarksville

Effect	Num DF	Den DF	F Value	P Value
Blk	3	3	1.83	0.3157
Row	1	3	24.44	0.0159
Pop	2	12	0.39	0.6884
Row*Pop	2	12	0.94	0.4171

Table 6. 2002 eastern black nightshade berry dry weight in Microplots as affected by soybean row spacings of 19- and 76-cm.

East Lansing in August

Effect	Num DF	Den DF	F Value	P Value
Blk	3	3	1.00	0.5000
Row	1	3	2.05	0.2472
Pop	2	12	0.37	0.6967
Row*Pop	2	12	0.37	0.6967

East Lansing in October

Effect	Num DF	Den DF	F Value	P Value
Blk	3	3	0.99	0.5023
Row	1	3	1.93	0.2593
Pop	2	12	0.89	0.4343
Row*Pop	2	12	0.88	0.4381

Clarksville in August

Effect	Num DF	Den DF	F Value	P Value
Blk	3	3	1.00	0.4989

Row	1	3	1.81	0.2711
Pop	2	12	0.92	0.4245
Row*Pop	2	12	0.90	0.4311

Clarksville in October

Effect	Num DF	Den DF	F Value	P Value
Blk	3	3	0.85	0.5508
Row	1	3	14.91	0.0307
Pop	2	12	1.58	0.2453
Row*Pop	2	12	1.56	0.2499

Table 7a. Effect of soybean row spacing, plant population, and eastern black nightshade on microplot soybean yield at East Lansing in 2002.

Effect	Num DF	Den DF	F Value	P Value
Row	1	3	1.06	0.3791
Pop	2	12	0.37	0.6955
Row*Pop	2	12	1.56	0.2509
Herb	1	18	0.33	0.5738
Row*Herb	1	18	0.68	0.4190
Pop*Herb	2	18	1.39	0.2745
Row*Pop*Herb	2	18	0.61	0.5545

Table 7b. Effect of soybean row spacing, plant population, and eastern black nightshade on microplot soybean yield at Clarksville in 2002.

Effect	Num DF	Den DF	F Value	P Value
Row	1	3	0.00	0.9534

Pop	2	12	0.22	0.8011
Row*Pop	2	12	1.08	0.3532
Herb	1	18	1.05	0.3139
Row*Herb	1	18	0.00	0.9610
Pop*Herb	2	18	1.14	0.3335
Row*Pop*Herb	2	18	3.02	0.0639

Table 8. Effect of soybean row spacing, population, and herbicide treatment on soybean yields at East Lansing in 2001.

Effect	Num DF	Den DF	F Value	P Value
Row	1	3	0.67	0.4738
Pop	1	6	27.30	0.0020
Row*Pop	1	6	0.00	0.9820
Herb	3	36	2.60	0.0674
Row*Herb	3	36	4.58	0.0081
Pop*Herb	3	36	0.28	0.8360
Row*Pop*Herb	3	36	1.76	0.1730

Table 9a. Effect of soybean row spacing, population, and herbicide treatment on soybean main plot yield at East Lansing in 2002.

Effect	Num DF	Den DF	F Value	P Value
Rep	3	3	4.26	0.1325
Row	1	3	0.05	0.8369
Pop	2	12	2.45	0.1281
Row*Pop	2	12	2.17	0.1570

Herb	3	54	2.26	0.0920
Row*Herb	3	54	1.36	0.2658
Pop*Herb	6	54	0.51	0.7963
Row*Pop*Herb	6	54	1.94	0.0907

Table 9b. Effect of soybean row spacing, population, and herbicide treatment on soybean main plot yield at Clarksville in 2002.

Effect	Num DF	Den DF	F Value	P Value
Rep	3	3	10.60	0.0005
Row	1	3	30.79	<0.0001
Pop	2	12	11.97	0.0008
Row*Pop	2	12	0.36	0.7031
Herb	3	54	8.18	0.0001
Row*Herb	3	54	0.53	0.6652
Pop*Herb	6	54	6.04	<0.0001
Row*Pop*Herb	6	54	1.61	0.1617

CHAPTER 3 ANOVA TABLES

Table 1. Effect of neutral density shading on the cumulative emergence of eastern black nightshade and hairy nightshade.

Source	DF	F Value	P Value
Rep	4	0.15	0.9608
Species	1	13.74	0.0004
Shade	3	3.70	0.0159
Species*Shade	3	0.79	0.5041

Table 2. Effects of neutral shading on reproductive, leaf, total dry weights, leaf area, and specific leaf area of eastern black nightshade and hairy nightshade.

Reproductive Dry Weight

Source	DF	F Value	P Value
Rep	3	0.33	0.8060
Species	1	2.40	0.1251
Shade	3	28.92	<0.0001
Species*Shade	3	0.42	0.7381

Leaf Dry Weight

Source	DF	F Value	P Value
Rep	3	0.12	0.9487
Species	1	7.08	0.0093
Shade	3	47.85	<0.0001
Species*Shade	3	0.12	0.9477

Total Dry Weight

Source	DF	F Value	P Value
Rep	3	0.14	0.9329
Species	1	1.82	0.1809
Shade	3	43.19	<0.0001
Species*Shade	3	0.09	0.9628

Leaf Area

Source	DF	F Value	P Value
Rep	3	0.16	0.9256
Species	1	14.30	0.0003
Shade	3	6.56	0.0005
Species*Shade	3	0.89	0.4481

Specific Leaf Area

Source	DF	F Value	P Value
Rep	3	1.48	0.2268
Species	1	1.09	0.2992
Shade	3	29.52	<0.0001
Species*Shade	3	0.66	0.5764

Table 3. Comparison of radiation quality on the reproductive, leaf, total dry weights, leaf area, and specific leaf area of eastern black nightshade and hairy nightshade.

Reproductive Dry Weight

Source	DF	F Value	P Value
Rep	3	0.33	0.8060
Species	1	2.40	0.1251
Shade	3	28.92	<0.0001
Species*Shade	3	0.42	0.7381

Leaf Dry Weight

Source	DF	F Value	P Value
Rep	3	0.12	0.9487
Species	1	7.08	0.0093
Shade	3	47.85	<0.0001
Species*Shade	3	0.12	0.9477

Total Dry Weight

Source	DF	F Value	P Value
Rep	4	0.15	0.9329
Species	1	13.74	0.1809
Shade	3	3.70	<0.0001
Species*Shade	3	0.79	0.9628

Leaf Area

Source	DF	F Value	P Value
Rep	3	0.16	0.9256
Species	1	14.30	0.0003
Shade	3	6.56	0.0005
Species*Shade	3	0.89	0.4481

Specific Leaf Area

Source	DF	F Value	P Value
Rep	3	0.34	0.7941
Species	1	4.62	0.0382
Shade	2	9.93	0.0004
Species*Shade	2	1.14	0.3304