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Patch expansion of purple nutsedge (*Cyperus rotundus*) and yellow nutsedge (*Cyperus esculentus*) with and without polyethylene mulch

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Purple and yellow nutsedge are the most troublesome weeds of vegetable crops in the southeast United States. Elimination of methyl bromide use will require alternative management programs to suppress nutsedge growth and interference in vegetables. Polyethylene mulch is an effective barrier for most weeds; however, nutsedges can proliferate in beds covered with polyethylene mulch. The influence of polyethylene mulch on shoot production and lateral expansion patterns of single tubers of purple nutsedge and yellow nutsedge over time was evaluated in field studies. Purple nutsedge patch size was similar in the black mulch treatment and nonmulched control after 8 and 16 wk after planting (WAP). By the end of the growing season, purple nutsedge patch size in the black mulch treatment was nearly twice that in the nonmulched control. At 32 WAP, there were 1,550 shoots in the 16.1 m^2 patch in the black mulch treatment and 790 shoots in the 8.1 m^2 patch in the nonmulched control. In contrast, yellow nutsedge growth was suppressed in the black mulch treatment, relative to the nonmulched control. Compared with the black mulch treatment at 16 and 24 WAP, the nonmulched control produced nearly three times as many yellow nutsedge shoots (140 shoots at 16 WAP and 210 shoots at 24 WAP) and patches that were twice the size (0.10 m^2 at 16 WAP and 0.18 m^2 at 24 WAP). These data indicate that there are significant differences in the growth habits of the two nutsedges species in mulched vegetable systems. The differences in response to black mulch will likely lead to purple nutsedge becoming a greater problem, relative to yellow nutsedge, in vegetable systems. The rapid expansion of a single purple nutsedge shoot to form a patch that is 22.1 m^2 and containing 3,440 shoots at 60 WAP illustrates the importance of managing this species.

Nomenclature: Purple nutsedge, *Cyperus rotundus* L. CYPRO; yellow nutsedge, *Cyperus esculentus* L. CYPES.

Key words: Polyethylene mulches, solarization, weed patches.

Purple and yellow nutsedge are exotic invasive weeds that have become naturalized within the United States. Yellow nutsedge was first listed as a weed in the United States in 1889 (Defelice 2002); by 1939, uncontrolled purple nutsedge encroachment caused growers to abandon agricultural land (Godfrey 1939). Purple nutsedge and yellow nutsedge are the most troublesome weeds of vegetable crops in Georgia and many states in the southern United States (Webster 2002; Webster and MacDonald 2001). Methyl bromide has been a critical component of annual fruit and vegetable systems to manage nutsedge species and other soil-borne pests (Julian et al. 1998; Ragsdale and Wheeler 1995; Schneider et al. 2003). The impending elimination of methyl bromide will increase the complexity of pest management in many vegetable crops. Several studies have identified potential short-term methyl bromide alternatives that include currently registered fumigants that are effective against several pest organisms, but nutsedge control is variable (Csinos et al. 2000; Desaeger et al. 2004; Gilreath and Santos 2004; Gilreath et al. 2004a, 2004b; Hutchinson et al. 2004; Johnson and Webster 2001; Webster et al. 2001). Future pest management systems will need to incorporate a combination of tactics to manage weeds (especially nutsedges) in high-value vegetable crop production (Cardina et al. 1999; Patterson 1998). A greater understanding of the ecology of nutsedges in vegetable production systems will be an initial step in devising appropriate management strategies.

Polyethylene mulch is a common component of fruiting vegetables and cucurbit production in the southeast United States. One benefit of polyethylene mulch is suppression of grass and broadleaf weed establishment. However, nutsedges are capable of penetrating mulch with a thickness of 127 μm, four times the thickness currently used in commercial vegetable production (Henson and Little 1969) and nutsedges will successfully compete with crops for resources (i.e., water, nutrients, and light) (Buker et al. 2003; Johnson and Mullinix 1999; Morales-Payan et al. 1997; Santos et al. 1997; William 1976). Previous studies have documented that mulches can affect tuber production of yellow nutsedge and purple nutsedge (Majek and Neary 1991; Patterson 1998; Webster 2005), but no study has evaluated the spatial growth patterns of the two species. The objective of this study was to evaluate the effect of polyethylene mulches on nutsedge growth and patch expansion over a growing season.

Materials and Methods

Field studies were initiated at the Jones Research Farm near Tifton, GA, in 2001 and 2002. The soil was a Tifton loamy sand (fine-loamy, kaolinitic, thermic Plinthic Kandiudults) consisting of 86% sand, 7% silt, 7% clay with 0.9 to 1.0% OM and pH of 6.3 to 6.5. Treatments were structured in a factorial arrangement with two species of nutsedge (purple nutsedge and yellow nutsedge) and three mulch barriers (black-opaque low density polyethylene [LDPE] mulch, thickness 32 μm; clear-colorless LDPE mulch, thickness 32 μm; and a nonmulched control). Plots were 5.5 m wide and 8 m long, consisting of three equally spaced raised beds. Each raised bed was 15 cm tall with a bed top of 76 cm, typical for vegetable production in the southeast United States, and included a single drip irrigation line. Drip irrigation tape had an output of 250 L h^{-1} 100 m^{-1} at 0.55 bar with emitters spaced 20 cm apart[1].

Plots were established in nutsedge-free areas. In the middle of each plot, a small hole was made in the mulch, through which a single presprouted purple nutsedge or yellow nutsedge tuber was transplanted. The study was arranged as a randomized complete block design (blocked by initial nutsedge tuber biomass) with three replications and was repeated over time.

Plots were divided into 12.7-cm by 12.7-cm quadrats, and the numbers of emerged nutsedge shoots in each quadrat that pierced the mulch were quantified, without disturbing the mulch, at 8, 16, 24, 32, and 60 WAP. Nutsedge shoot numbers for each species and mulch type were regressed over time and fit to linear models (yellow nutsedge) and sigmoid models (purple nutsedge). Spatial data for purple nutsedge shoot density were analyzed using previously described geostatistical procedures (Cardina et al. 1995; Webster et al. 2000). Kriged maps of purple nutsedge shoot densities were created for each patch at five time the intervals and patch size determined from these maps. Data were subjected to analysis of variance and regressed over time using a sigmoid model. Lack of success during initial establishment of purple nutsedge in clear mulch prevented the inclusion of this data, therefore only the black mulch and nonmulched treatments were included in the analysis. Yellow nutsedge shoots were evaluated up to 24 WAP because shoots were brown and desiccated at 32 WAP, and low winter survivorship eliminated data at 60 WAP from the analysis. Accurate estimates of yellow nutsedge patches could not be obtained from the kriged maps because of the quadrat size and minimal movement of the yellow nutsedge. Instead, yellow nutsedge patch size was estimated by summing the number of quadrats at each time interval that contained at least one yellow nutsedge shoot. The number of quadrats with a yellow nutsedge shoot was regressed over time for each mulch type using linear models.

Results and Discussion

Purple Nutsedge

There was a sigmoidal increase in purple nutsedge shoot populations over time ($R^2 \geq 0.73$, $P \leq 0.0001$) in both the black mulch treatment and nonmulched control (Figure 1). During the first 8 wk of the season, purple nutsedge produced ≤ 6 shoots per plot in both the black mulch treatment and nonmulched control. Previous research on purple nutsedge growth in nonmulched systems after 8 wk consisted of 11 shoots (Horowitz 1972). Between 8 and 16 WAP, there was exponential growth in the number of shoots, with 90 and 130 shoots added in the nonmulched control

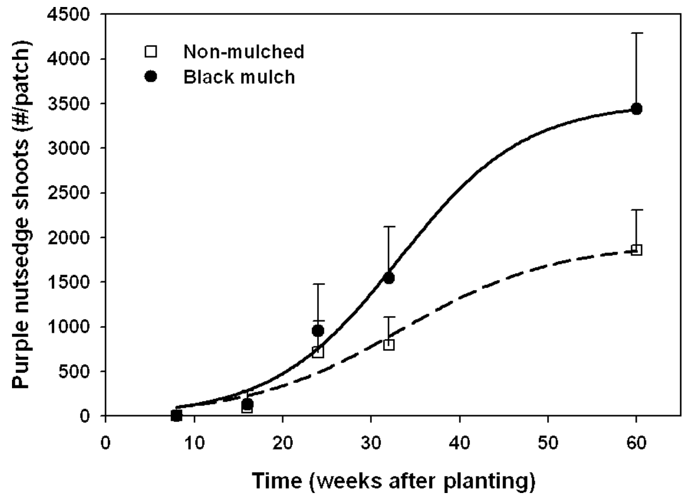

FIGURE 1. The influence of black polyethylene mulch on the relationship between purple nutsedge shoot number and time after planting with standard error around each mean. Nonmulched control: $y = 1{,}932/(1 + \exp[-\{x - 33.7\}/8.6])$, $R^2 = 0.73$, $P < 0.0001$; Black mulch: $y = 3{,}508/(1 + \exp[-\{x - 33.1\}/7.1])$, $R^2 = 0.77$, $P < 0.0001$.

and the black mulch treatment, respectively (Figure 1). Previous research demonstrated that after 12 wk of growth, purple nutsedge averaged 70 shoots per initial tuber planted when tubers were planted 30.5 cm spacings (Hauser 1962b). By 24 WAP, 950 purple nutsedge shoots were produced in the black mulch treatment, an increase of 33% more shoots than the nonmulched control (715). The rate of increase between 16 and 24 WAP was 103 and 77 new shoots per week for the black mulch treatment and nonmulched control, respectively. The rate of increase slowed between 24 and 32 WAP (coinciding with autumn weather consisting of warm days and cool nights) to 74 and 10 new shoots per week in the black mulch treatment and nonmulched control, respectively. There were 1,550 purple nutsedge shoots in the black mulch treatment at 32 WAP and 790 shoots in the nonmulched control. The onset of autumn weather patterns likely caused purple nutsedge growth differences between the black mulch treatment and the nonmulched control, attributed to the ability of the black mulch treatment to moderate these temperatures relative to the nonmulched control. Previous studies have indicated that in areas where water is not limited, an apt description of mulched vegetable systems in the southeast United States, purple nutsedge shoot growth is strongly dependent upon temperature (Horowitz 1965, 1972).

In both the black mulch treatment and the nonmulched control, the number of purple nutsedge shoots more than doubled between 32 WAP (November) and 60 WAP (May) (Figure 1). During this interval, 1,890 new shoots were produced in the black mulch treatment, whereas only 1,060 new shoots were produced in the nonmulched control. At 60 WAP, the black mulch treatment had 1.8 times more shoots (3,440 shoots) than the nonmulched control (1,860 shoots). Emerged purple nutsedge shoots were killed by frost in each year of the study. However, relative to the nonmulched control, the soil in the black mulch treatment was likely warmed earlier in the season. Previous research documents that compared with bare soil, temperatures under black mulch increased 4 to 10 C (at depths of 1 to 6 cm) and 10 to 11 C (at 5 cm depth) in Louisiana and Florida,

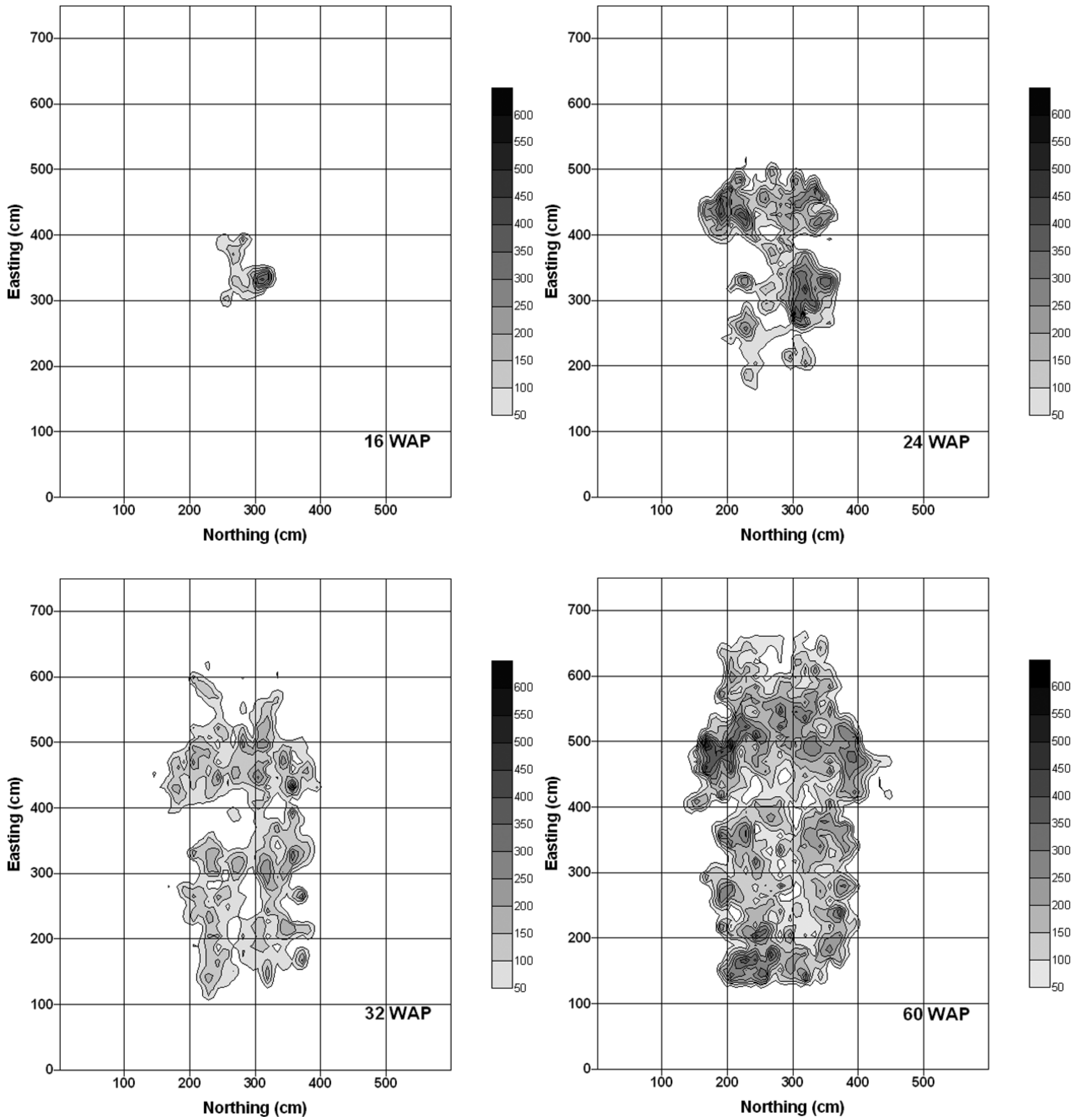

FIGURE 2. Expansion of a single purple nutsedge shoot, in the absence of black polyethylene mulch, to form patches at 16, 24, 32, and 60 wk after planting (WAP). Kriged estimates of purple nutsedge population density range from 50 (lighter color) to 600 (darker color) plants m^{-2}.

respectively (Chase et al. 1999; Standifer et al. 1984). The minimum soil temperature for purple nutsedge tuber sprouting and production is 19 C (Horowitz 1972, 1992). Continuous nonzero growing degree day accumulation at 5 cm soil depth in nonmulched soil began March 22, 2001, and April 9, 2002. Applying estimates of black mulch–induced increases in soil temperatures between 4 and 10 C (Chase et al. 1999; Standifer et al. 1984), nonzero growing degree day accumulation in the black mulch treatment began in 2001 between January 12 and February 14 and in 2002 between January 10 and March 12. The warmer soil temperatures of a black mulch–covered bed could support purple nutsedge growth 1 to 3 mo earlier than in nonmulched soils.

Over time, purple nutsedge shoots formed nearly elliptical patches (Figures 2 and 3). Patch expansion, and the overall shape of the patch, was likely influenced by readily available water from drip irrigation, which was placed in the center of each raised plant bed. The area of the patch that developed from each initial purple nutsedge plant expanded over time in a sigmoidal manner ($R^2 \geq 0.81$, $P \leq 0.0001$). At 8 WAP, purple nutsedge shoots were found within the center

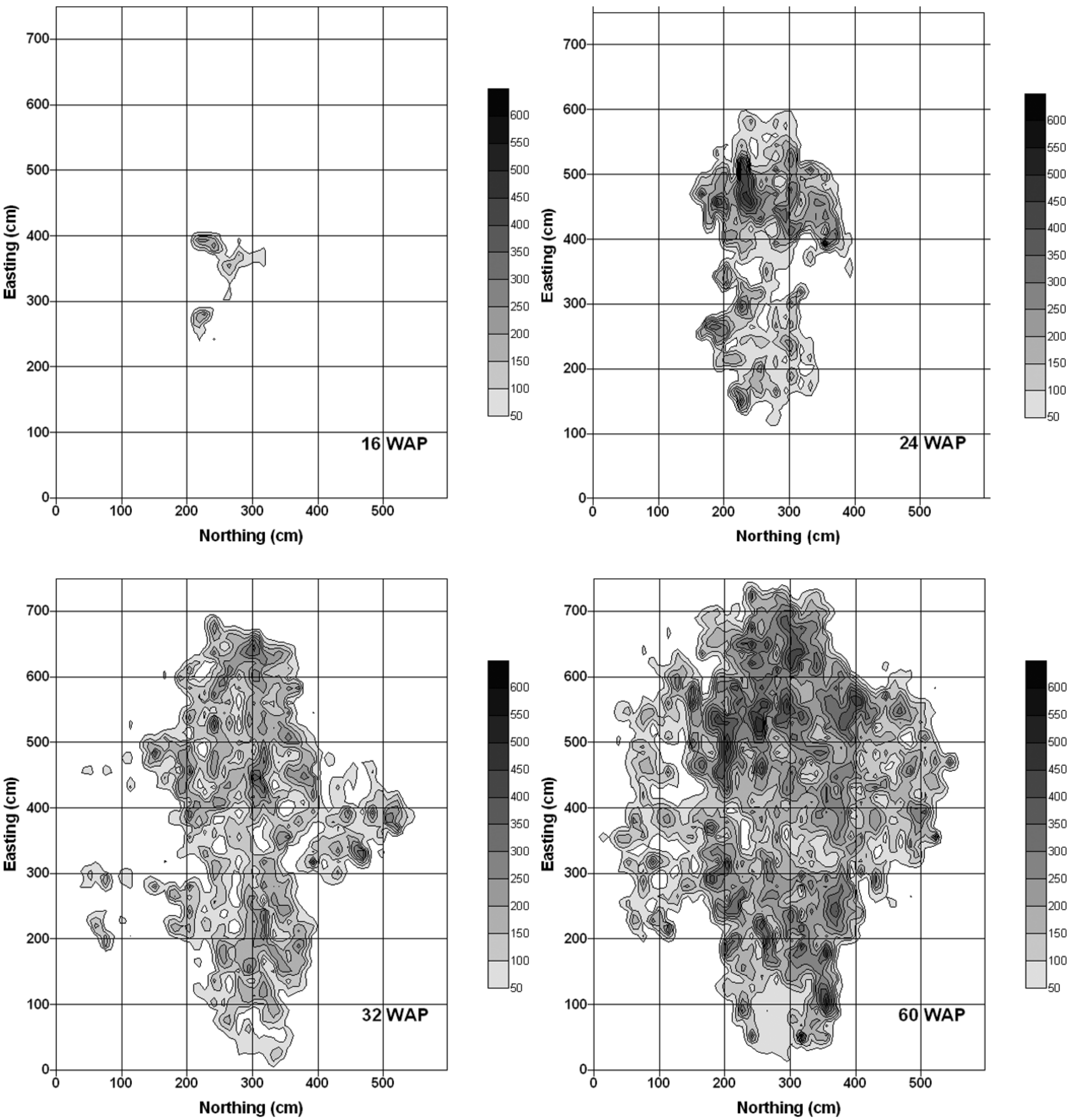

FIGURE 3. Expansion of a single purple nutsedge shoot, in black polyethylene mulch systems, to form patches at 16, 24, 32, and 60 wk after planting (WAP). Kriged estimates of purple nutsedge population density range from 50 (lighter color) to 600 (darker color) plants m^{-2}.

quadrat and two to four adjacent quadrats, forming patches of 0.05 to 0.08 m^2 (Figure 4). Purple nutsedge patches grew to between 1.35 and 1.1 m^2 after 16 WAP in the black mulch treatment and nonmulched control, respectively. By 24 WAP, subtle differences between the black mulch treatment and nonmulched control were beginning to appear; patches grew in area to 5.5 m^2 and 7.6 m^2 in the nonmulched control and black mulch treatment, respectively, expanding between 16 and 24 WAP at rates of 0.55 and 0.78 m^2 wk^{-1} for the nonmulched control and black mulch treatment, respectively. Similar to the trend observed with shoot population, rate of patch expansion between 24 and 32 WAP was greater in the black mulch treatment (1.06 m^2 wk^{-1}) than for the nonmulched control (0.33 m^2 wk^{-1}). At 32 WAP, patch area in the black mulch treatment was 16.1 m^2, nearly twice the size of patches in the nonmulched controls (8.1 m^2). At the conclusion of one season of growth in nonmulched areas, previous research determined that a single purple nutsedge plant formed a 7.6 m^2 patch (Horowitz 1972), which is similar to the nonmulched control

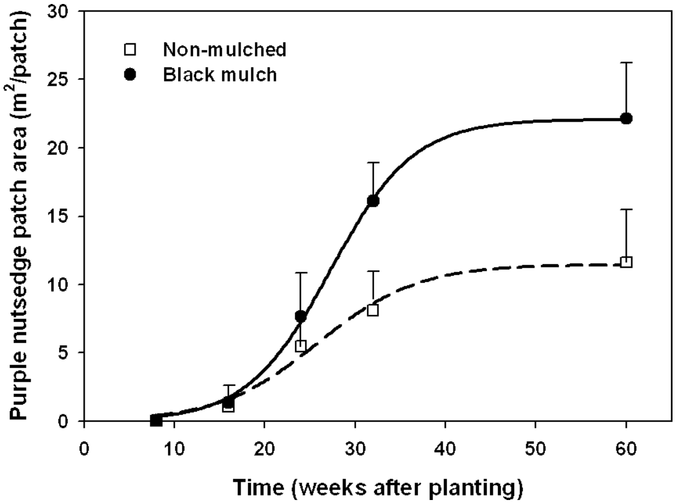

FIGURE 4. The relationship between purple nutsedge patch area and time after planting as affected by black polyethylene mulch with standard error around each mean. Nonmulched control: $y = 12.8/(1 + \exp[-\{x - 25.7\}/5.5])$, $R^2 = 0.90$, $P < 0.0001$; Black mulch: $y = 22.8/(1 + \exp[-\{x - 27.6\}/4.8])$, $R^2 = 0.81$, $P < 0.0001$.

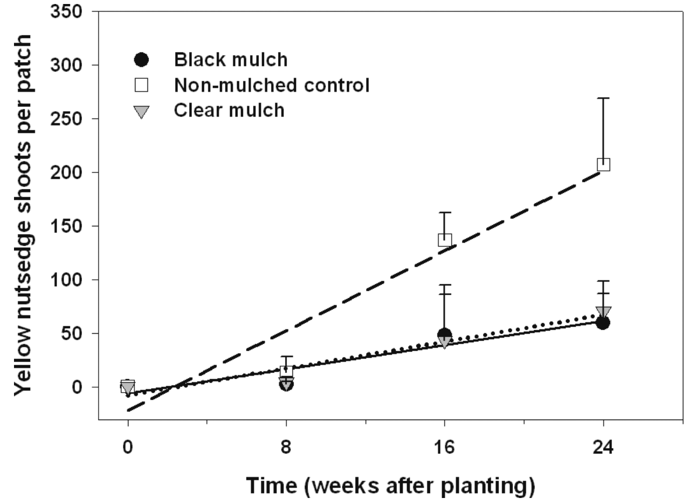

FIGURE 5. The influence of black polyethylene mulch, clear polyethylene mulch and the nonmulched control on the relationships between yellow nutsedge shoot number and time after planting with standard error around each mean. Nonmulched control: $y = 9.3 \times -21.5$, $R^2 = 0.89$, $P = 0.003$; black polyethylene mulch: $y = 2.8 \times -5.3$, $R^2 = 0.83$, $P = 0.005$; clear polyethylene mulch: $y = 3.1 \times -7.3$, $R^2 = 0.88$, $P = 0.003$.

at 32 WAP (Figure 4). At 60 WAP, patches in the black mulch treatment were 22.1 m^2, 1.9 times the size of patches in the nonmulched controls.

Yellow Nutsedge

There were linear relationships between the number of yellow nutsedge shoots and the time for the black mulch treatment ($R^2 = 0.83$, $P = 0.005$), clear mulch treatment ($R^2 = 0.88$, $P = 0.003$), and nonmulched control ($R^2 = 0.89$, $P = 0.003$). Both black and clear mulch treatments suppressed growth of yellow nutsedge shoots relative to the nonmulched control. During the initial 8 wk of the season, 13 new shoots were added in the nonmulched control, whereas two and four new shoots were added in the black mulch and clear mulch treatments, respectively (Figure 5). Between 8 and 16 WAP, new shoots emerged in the nonmulched control at a rate of 15.4 wk^{-1}, whereas the black and clear mulch treatments added 5.6 and 4.8 new shoots wk^{-1}, respectively. Over the season, the slopes of the regression indicated that the nonmulched control yielded ≥ three times the number of shoots compared with the black and clear mulch treatments. By 16 and 24 WAP, the black nonmulched control had 137 and 208 yellow nutsedge shoots, respectively.

Yellow nutsedge patches expanded in a radial manner and within close proximity to the initial plant, relative to purple nutsedge. There were linear relationships between the number of quadrats with a yellow nutsedge shoot and the time after planting ($R^2 = > 0.94$, $P < 0.0161$) (Figure 6). At 8 WAP, yellow nutsedge remained in the initial quadrat in the black mulch treatment and nonmulched control, whereas there was limited movement from the center quadrat in the clear mulch treatment. At 16 and 24 WAP, the black mulch treatment suppressed yellow nutsedge patch expansion to nearly half of that in the nonmulched control (0.10 and 0.18 m^2, respectively). This is in stark contrast to observations with purple nutsedge, in which patch growth was stimulated by black mulch. Although the clear mulch treatment reduced yellow nutsedge shoot populations relative to the nonmulched control, the size of the patches were similar to the nonmulched control.

In summary, the two most troublesome weeds of mulched-vegetable systems in the southeast United States had distinctly different patterns of growth. Purple nutsedge thrived in the black mulch treatment, producing a greater number of shoots and larger patch area relative to the nonmulched control. Yellow nutsedge growth was suppressed by black and clear mulch treatments relative to the nonmulched control. Previous research demonstrated that < 40% of the purple nutsedge shoots were prevented from piercing black mulch (Chase et al. 1999; Webster 2005), whereas ≥ 89% of yellow nutsedge shoots were trapped beneath black mulch (Majek and Neary 1991; Webster 2005). Also, the growth habit of purple nutsedge is contrasted with that of

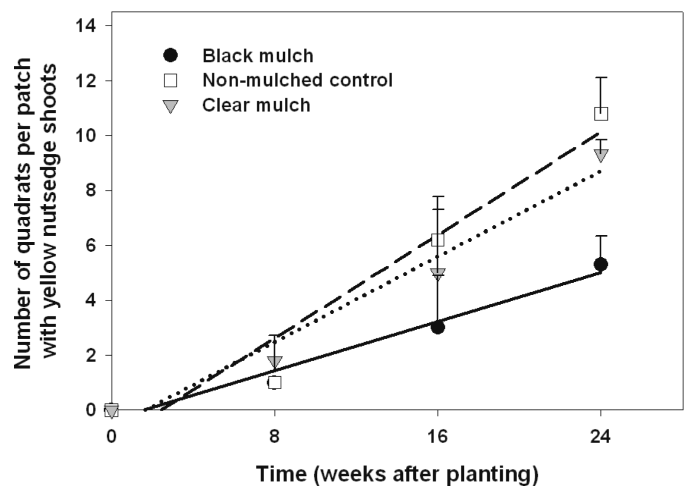

FIGURE 6. Expansion of yellow nutsedge shoots over time with standard error around each mean. Nonmulched control: $y = 0.47 \times -1.14$, $R^2 = 0.94$, $P = 0.0013$; black polyethylene mulch: $y = 0.22 \times -0.36$, $R^2 = 0.97$, $P = 0.0161$; clear polyethylene mulch: $y = 0.39 \times -0.65$, $R^2 = 0.97$, $P = 0.004$.

yellow nutsedge in the absence of mulch, a phenomenon likely related to the differences in growth habit of the two nutsedge species. Purple nutsedge tubers grow in a chain away from the initial tuber (Wills 1998), whereas yellow nutsedge possesses terminal tubers (Mulligan and Junkins 1976). Purple nutsedge was propagated throughout its environment, whereas yellow nutsedge remained relatively close to the initial tuber. This supports previous research in which the natural spread of yellow nutsedge was limited to < 1 m yr^{-1} (Schippers et al. 1993). Field equipment will distribute tubers of both species (De Vries 1991; Horowitz 1965; Schippers et al. 1993; Tumbleson and Kommedahl 1961) and stimulate dormant tubers by removing the apical dominance within a series of tubers (Hauser 1962a; Horowitz 1972; Nishimoto 2001). Compared with purple nutsedge, it appears that yellow nutsedge may be more dependent upon human disturbance for perpetuating and spreading this species throughout agricultural fields. Many growers will use the same polyethylene mulch–covered beds for multiple growing seasons, often a spring crop followed by an autumn crop followed by another spring crop. Reuse of polyethylene mulch and drip tape irrigation distributes the costs of these inputs over several seasons. The lack of soil disturbance in multiple season-mulch covered bed systems may promote purple nutsedge growth and suppress yellow nutsedge growth. Promotion of purple nutsedge growth by black mulch may have significant consequences for fields with purple nutsedge. Previous research demonstrated that elevated mean soil temperature and daily temperature fluctuations found in polyethylene mulch–covered beds promoted purple nutsedge tuber sprouting (Miles et al. 1996, 2002; Nishimoto 2001). The use of black polyethylene mulch may alter the environmental characteristics of the cropping system (i.e., extended growing seasons because of increased soil temperatures and minimal interspecific weed interference) to the benefit of purple nutsedge. For growers who use black mulch–covered beds for multiple crops, nutsedge control between vegetable crop seasons and in non-vegetable rotational crops is crucial in an overall management plan.

Sources of Materials

[1] Drip irrigation tape, T-Systems International, Inc. Corporate Headquarters, 7545 Carroll Rd., San Diego, CA 92121.

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