# SUMMER SOLARIZATION AND FALLOW TILLAGE TO CONTROL YELLOW NUTSEDGE AND NEMATODES

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## Introduction

Perennial nutsedges are among the most common and troublesome weeds of vegetable crops in Georgia. Yellow nutsedge (*Cyperus esculentus* L.) and purple nutsedge (*Cyperus rotundus* L.) reduce crop yield through competition and allelopathy. Perennial nutsedges are also costly to control in vegetable crops and reduce the useful life of thin-film mulches by puncturing the mulch. Perennial nutsedges are managed by an integration of soil fumigants, selective herbicides, and cultural practices that favor crop growth. However, soil fumigants and synthetic herbicides are not viable options in organic crop production and home vegetable gardens.

Soil solarization is a means of pest control by which the soil is heated to lethal temperatures using solar radiation. Typically, solarization is practiced in regions of intense sunlight, such as the tropics or arid regions that have little cloud cover. Moistened seedbeds are covered with clear polyethylene mulch and remain covered for an extended period of time. During the solarization period, 85 to 95% of radiation from sunlight penetrates the clear mulch and heats the soil. Water droplets accumulate on the under-surface of the clear mulch which retain heat and insulate the seedbed. Soil temperatures average at least 6 C greater under the clear polyethylene mulch than in non-covered seedbeds, depending on depth in the soil profile. It is theorized that solarization controls weeds by direct thermal killing of propagules, high temperatures interacting with toxic volatiles from decaying organic matter that weaken weed propagules so they are predisposed to microbial infection, and breaking propagule dormancy followed by scorching of weeds trapped under the clear solarization mulch.

Opaque mulches are not effective as solarization agents. Insufficient light penetrates opaque mulch to heat the soil. Furthermore, perennial nutsedges readily penetrate opaque mulches since leaf buds remain unfolded allowing the leaf sheaths to puncture the film.

Solarization has been shown to control a broad array of plant pests including weeds, nematodes, fungi, and insects. In general terms, annual weeds are more effectively controlled than perennial weeds by solarization. However, there are indications that perennial weeds can be effectively controlled, albeit inconsistently. In studies conducted in Israel, soil solarization effectively controlled purple nutsedge. However, soil solarization did not effectively control purple nutsedge in other trials conducted in California. Furthermore, purple nutsedge densities were increased by soil solarization trials in Mississippi and in India. Other trials from Florida reported effective control of a mixed infestation of perennial nutsedges, although the individual species responses were not differentiated. Recently, studies showed that yellow nutsedge tubers are more sensitive to heat than purple nutsedge tubers, with temperature >50 C necessary for tuber mortality of both species. This suggests a potential differential response to soil solarization between the two species, particularly in regions that have marginal soil heating due to latitude or periods of excessive cloud cover.

Previous research suggests that the inconsistent efficacy of soil solarization on weeds, particularly perennial nutsedges, is likely due to the inability to raise soil temperatures to a level lethal to tubers and insufficient duration of exposure to high soil temperatures. These environmental factors are influenced by latitude, time of the year, and cloud cover. Weed species composition and depth of weed propagule placement further influences soil solarization efficacy. Despite inconsistent efficacy, soil solarization is a viable option for pest control in organic cropping systems and a tool in the transition from conventional crop production to organic crop production.

Fallow tillage is another proven method of weed control that does not depend on soil fumigants or synthetic herbicides. Several studies have shown that weed propagule numbers in the plow layer can be reduced by repeated tillage that stimulates emergence. In a fallow field, weed emergence was induced with frequent tillage for 4 yr. Afterwards, tillage had no effect, implying that the weed seeds in the plow layer had been depleted. In studies from the 1930's, purple nutsedge was eradicated from a field in Alabama by disk harrowing at weekly or biweekly intervals for 5 months. While any form of shallow tillage may stimulate weed emergence, soil pulverization by an implement such as a power tiller is preferable. Such implements destroy clods, provide better soil-weed seed contact, and create soil conditions conducive for seed germination.

Soil solarization and fallow tillage have been independently evaluated and shown to be useful tools to control perennial nutsedges. However they have not been studied together as part of an integrated system, particularly in temperate regions of the southeastern U. S. It is hypothesized that an integrated system of summer solarization and fallow tillage would effectively control perennial nutsedges and nematodes in certain high-value production systems in the temperate southeastern U. S. This system would be useful in organic crop production systems and home gardens.

## <u>Materials and Methods</u>

Irrigated field trials were conducted from 2002 to 2005 at the Coastal Plain Experiment Station Ponder Farm near Ty Ty, GA. The soil was a Tifton loamy sand, composed of 88% sand, 6% silt, and 6% clay, with 0.2% organic matter and pH 6.4. These trials were conducted at sites with heavy natural infestations of yellow nutsedge (>150 plants/$m^2$).

The experimental design was a randomized complete block, with treatments replicated four times. Treatments included all possible combinations of time at which solarization was initiated and frequency of fallow tillage. Plots were 3.6 m wide and 6.1 m long. Times when solarization treatments were initiated were early May, early July, early September, and a non-solarized control. Solarization mulch was clear-colorless polyethylene in sheets 3.7 m wide and cut to the length of the plot. The solarization mulch was 4-mil thick in 2003 and 6-mil thick in 2004 and 2005. All plots were weed free and irrigated to field capacity at the time of applying solarization mulch. Solarization mulch was applied by hand, with edges buried to anchor the mulch.

Frequencies of fallow tillage were weekly, monthly, and a non-tilled control. Plots were fallow-tilled using a power-tiller that tilled a swath 1.8 m wide and 7.6 cm deep. In each case, fallow tillage operations were conducted according to protocol until application of solarization mulch, after which fallow tillage ceased for that treatment. Excessive rainfall occasionally prevented weekly fallow-tillage operations. As a result of the factorial experimental design and weather events that interrupted weekly tillage, there were differing numbers of fallow tillage operations among the solarization treatments. The actual number of tillage operations for each treatment are listed by year in Table 1.

Soil temperature was measured at a depth of 10 cm under solarization mulch and a non-covered bareground control. Soil temperatures were collected every 30 minutes and recorded on a datalogger. Data were summarized according to maximum daily soil temperature at 10 cm under solarization mulch and non-covered bareground.

In early October of each year, all solarization mulch was removed. Plant parasitic nematodes were sampled by collecting six cores

(2.5 cm diameter and 15 cm deep) from each plot with nematodes assayed from a 150 $cm^3$ sub-sample using the centrifugal flotation method. Yellow nutsedge tubers were sampled by collecting two cores per plot (10 cm diameter and 15 cm deep), with tubers counted by sieving soil through a galvanized screen with a mesh size of 6 mm. All plots were then lightly disked to remove emerged weeds, where present. Turnip green were direct seeded into the prepared seedbed in rows spaced 91 cm apart. Turnip green was chosen since there are no effective controls for yellow nutsedge and the weed contaminates the harvested commodity. In mid-November each year, turnip green yields were measured and yellow nutsedge emergence was counted each plot. Plots were lightly disk harrowed and planted to sweet corn the following spring. Yellow nutsedge densities in sweet corn were evaluated in late-April.

## Results and Discussion

Soil temperatures at the 10 cm depth were consistently greater under the solarization mulch than in bareground throughout the term of the study (Figure 1). This is in agreement with results from earlier solarization studies using clear-colorless solarization film. Soil temperatures at 10 cm under solarization mulch averaged 48 C compared to 41 C in non-covered control plots, with a treatment period of 153 and 90 days for solarization beginning in May and July, respectively. In Mississippi, soil temperatures at 5 cm under solarization mulch averaged 58 C compared to 35 C in non-covered plots, with a solarization period of 28 days. Soil temperatures in central Florida at 10 cm under clear-colorless solarization film to averaged 43 C compared to 35 C in non-covered plots, with a solarization period of 41 days.

Summer solarization beginning in May or July, with and without periodic fallow tillage, effectively controlled yellow nutsedge in autumn-seeded turnip green (Table 2). When summer solarization was initiated in May or July, there was no difference in yellow nutsedge control in autumn-seeded turnip green regardless of the fallow-tillage regime. This indicates the effectiveness of summer solarization in controlling yellow nutsedge without having to use periodic fallow tillage. Summer solarization beginning in September controlled yellow nutsedge in autumn-seeded turnip green, provided that fallow seedbeds were either monthly or weekly tilled throughout the preceding summer (Table 2). Without periodic fallow tillage, solarization beginning in September was not effective in controlling yellow nutsedge. Numbers of yellow nutsedge tubers in the soil were reduced by solarization beginning in May or July, and by fallow tillage at monthly or weekly intervals (Table 2). Reducing tuber density is a critical component of any long-term strategy to manage yellow nutsedge.

Fallow tillage alone at monthly or weekly intervals throughout the summer effectively controlled yellow nutsedge in autumn-seeded turnip green (Table 2). Throughout the trial, there was no difference seen in yellow nutsedge control between monthly and weekly fallow tillage regimes. There is little reason to till fallow fields any more than five times at monthly intervals throughout the summer, otherwise the cost of extra fallow tillage operations exceeds any possible pest control benefit.

Turnip green yield response to summer solarization and fallow tillage was similar to the response of yellow nutsedge (data not shown). The greatest turnip green yields were in plots that were solarized beginning in May or July, along with plots that were fallow tilled at monthly or weekly intervals. Turnip green yield in non-tilled plots that were solarized beginning in September or the non-solarized, non-tilled control possessed the lowest turnip green yields of all treatment combinations.

The effects of summer solarization and fallow tillage were also expressed when sweet corn was seeded the following spring (Table 2). The most efficacious treatment combinations in controlling yellow nutsedge in autumn-seeded turnip green were also equally effective in controlling the weed in spring seeded sweet corn. Solarization beginning the preceding May or July reduced yellow nutsedge densities and the effect was seen the following growing season. Similarly, fallow tillage alone at monthly or weekly intervals reduced yellow nutsedge densities equally well as summer solarization and these effects were still evident the following spring in sweet corn.

All combinations of summer solarization and fallow tillage reduced numbers of juvenile root-knot nematode compared to the non-solarized non-tilled control (Table 3). Densities of stubby-root and ring nematode were less in plots solarized starting in May or July. However, both nematode species were present in greater numbers when solarized starting in September. In the absence of solarization, monthly and weekly fallow tillage reduced numbers of stubby-root and ring nematodes. Response of root-knot, stubby-root, and ring nematodes to solarization and fallow treatments was nearly identical to the response of yellow nutsedge. It should be noted that yellow nutsedge is a relatively poor host to root-knot nematode. Since yellow nutsedge is a poor host of root-knot nematode, it is likely that the response of root-knot nematode to solarization and fallow tillage is due to direct treatment effects on the nematode, though reduced densities of a poor alternate host (yellow nutsedge) also may have an effect.

It is clear that in southern Georgia, it is possible to heat soil sufficiently to control yellow nutsedge and nematodes, provided solarization is conducted in the summer months (May through September). Compared to tropical or arid regions, the effect of our cooler soil temperatures can be compensated by extending the solarization period to at least 90 days. Organic growers and home gardeners have few options to manage perennial nutsedges and nematodes. Sacrificing the use of a troublesome field for a summer and using a system of solarization and fallow tillage is a viable means by which these pests can be managed in the absence of fumigants and synthetic herbicides. If possible, solarization or fallow tillage beginning in May would be the best option of the choices available since there is ample time to hedge against periods of excessive cloud cover and rainfall which would cool the soil and also hinder fallow tillage. Solarization beginning in July is a viable option since it would allow for planting and harvesting of spring crops, and still achieve adequate weed and nematode control. If solarization is not possible, fallow tillage at monthly intervals is effective and not nearly as costly and disruptive to soil stewardship as weekly tillage.

**Table 1. Actual number of fallow tillage operations for each solarization regime, 2003 to 2005.**

| | | Number of tillage operations | | |
|---|---|---|---|---|
| | | 2003 | 2004 | 2005 |
| Solarization starting in May | | | | |
| | Tilled weekly | 1 | 1 | 1 |
| | Tilled monthly | 1 | 1 | 1 |
| | Non-tilled | 0 | 0 | 0 |
| Solarization starting in July | | | | |
| | Tilled weekly | 5 | 7 | 5 |
| | Tilled monthly | 2 | 2 | 2 |
| | Non-tilled | 0 | 0 | 0 |
| Solarization starting in September | | | | |
| | Tilled weekly | 9 | 13 | 12 |
| | Tilled monthly | 4 | 4 | 4 |
| | Non-tilled | 0 | 0 | 0 |
| No solarization | | | | |
| | Tilled weekly | 11 | 15 | 14 |
| | Tilled monthly | 5 | 4 | 5 |
| | Non-tilled | 0 | 0 | 0 |

**Table 2. Effect of summer solarization and fallow tillage on yellow nutsedge density and turnip green yield; Tifton, GA 2003 to 2005.**

| | | Average number of tillages | Yellow nutsedge in autumn-seeded turnip green | | Yellow nutsedge in sweet corn seeded the following spring[1] |
|---|---|---|---|---|---|
| | | | Plant density (no/m$^2$) | Tubers in soil (no./m$^3$) | Density (no/m$^2$) |
| Solarization starting in May | | | | | |
| | Non-tilled | 0 | 0.0 | 875 | 1.9 |
| | Tilled weekly | 1 | 0.1 | 944 | 2.6 |
| | Tilled monthly | 1 | 0.3 | 940 | 3.8 |
| Solarization starting in July | | | | | |
| | Non-tilled | 0 | 2.3 | 1817 | 27.3 |
| | Tilled weekly | 6 | 0.1 | 876 | 1.2 |
| | Tilled monthly | 2 | 0.3 | 1211 | 3.4 |
| Solarization starting in Sept. | | | | | |
| | Non-tilled | 0 | 19.9 | 2810 | 108.9 |
| | Tilled weekly | 11 | 0.5 | 707 | 1.2 |
| | Tilled monthly | 4 | 1.1 | 607 | 1.9 |
| No solarization | | | | | |
| | Non-tilled | 0 | 17.7 | 3487 | 178.7 |
| | Tilled weekly | 13 | 0.2 | 941 | 0.8 |
| | Tilled monthly | 5 | 0.9 | 707 | 3.4 |
| LSD (0.05) | | | 11.3 | 1464 | 35 |

[1]Sweet corn seeded in plots the spring after solarization and fallow tillage treatments were conducted the preceding year.

**Table 3. Effect of summer solarization and fallow tillage on nematodes; Tifton, GA 2003 to 2005.**

| | | Average number of tillages | Juvenile root-knot nematode | Stubby-root nematode | Ring nematode |
|---|---|---|---|---|---|
| | | | --------------(no./150 $cm^3$ soil)-------------- | | |
| Solarization starting in May | | | | | |
| | Non-tilled | 0 | 0.8 | 0.8 | 0.0 |
| | Tilled weekly | 1 | 0.0 | 2.5 | 0.0 |
| | Tilled monthly | 1 | 2.5 | 1.7 | 0.0 |
| Solarization starting in July | | | | | |
| | Non-tilled | 0 | 1.7 | 1.7 | 1.7 |
| | Tilled weekly | 6 | 0.8 | 1.7 | 1.7 |
| | Tilled monthly | 2 | 0.0 | 2.5 | 0.0 |
| Solarization starting in Sept. | | | | | |
| | Non-tilled | 0 | 3.3 | 10.8 | 38.3 |
| | Tilled weekly | 11 | 6.7 | 4.2 | 4.2 |
| | Tilled monthly | 4 | 2.5 | 5.8 | 5.8 |
| No solarization | | | | | |
| | Non-tilled | 0 | 24.2 | 10.8 | 25.0 |
| | Tilled weekly | 13 | 1.7 | 1.7 | 1.7 |
| | Tilled monthly | 5 | 1.7 | 5.8 | 1.7 |
| LSD (0.05) | | | 12.3 | 7.4 | 22.8 |

[1]Sweet corn seeded in plots the spring after solarization and fallow tillage treatments were conducted the preceding year.

**Figure 1.** Soil temperature comparison at 10 cm between solarized plots and bareground plots. Missing data due to soil temperature probes displaced by wildlife or storms. May, July, and September solarization periods initiated on Julian dates 129, 188, and 248, respectively.