Proc. Fla. State Hort. Soc. 115:189-192. 2002.

EFFICACY OF 1,3-DICHLOROPROPENE + CHLOROPICRIN AND METAM-NA ON YELLOW NUTSEDGE TUBERS PLANTED AT VARYING GROWTH STAGES

TIMOTHY N. MOTIS[1] AND SALVADORE J. LOCASCIO
University of Florida
Horticultural Sciences Department
Gainesville, FL 32611-0690

JAMES P. GILREATH
University of Florida
Gulf Coast Research and Education Center
Bradenton, FL 34203

Additional index words. Cyperus esculentus, Vapam, Telone C-35

Abstract. **The fumigants 1,3-dichloropropene (1,3-D) + chloropicrin (Pic) and metam-Na have provided erratic nutsedge (*Cyperus spp.*) control in the field. To determine if the activity of these fumigants against yellow nutsedge (*Cyperus esculentus* L.) varies with tuber growth stage, a greenhouse experiment was conducted using two fumigation treatments (1,3-D + 35% Pic at 327 L·ha^{-1} and metam-Na at 294 L·ha^{-1}) and a nonfumigated control, two tuber sources (Gainesville and Quincy), three tuber growth stages (dry, water-imbibed, and sprouted at planting), and two metam-Na rates (147 or 589 L·ha^{-1}) applied to imbibed tubers. Pans containing the soil and tubers were covered with polyethylene film for 3 d after treatments (DAT). In spring 2000, both fumigants provided 100% nutsedge control. In winter 2001, metam-Na provided 100% nutsedge control while 1,3-D + Pic provided near total control with greater activity against imbibed than dry tubers. Nutsedge control of ≥89% was obtained with both fumigants for 28 DAT. Results indicated that nutsedge activity of 1,3-D + Pic may be optimized by irrigation prior to treatment, and that of both fumigants enhanced by minimizing fumigant out-gassing.**

Yellow nutsedge (*Cyperus esculentus* L.), a common weed in Florida, is difficult to control because it propagates by underground tubers that are usually present at varying stages of growth and have two to seven buds on each tuber (Thullen and Keeley, 1975). The sprouting rhizome tips easily penetrate polyethylene mulch commonly used in vegetable production. Interference from uncontrolled yellow nutsedge has substantially reduced vegetable yields (Buker, 1999; Morales-Payan et al., 1997; Motis et al., 2001).

Methyl bromide alone or with chloropicrin (Pic) has been used to control yellow and purple (*Cyperus rotundus* L.) nutsedges since the early 1970s (Overman and Martin, 1978) because it is easy to apply and has strong activity against nutsedges, soil diseases, and nematodes under a wide range of conditions. Due to its alleged contribution to ozone depletion, however, methyl bromide is scheduled to be phased out of production and use in the U.S.A. by 2005 (Environmental Protection Agency, 1999).

Sodium N-methyldithiocarbamate (Metam-Na) and 1,3-dichloropropene (1,3-D) are two commercially available chemical alternatives to methyl bromide. Usually 1,3-D, primarily a nematicide, is combined with Pic for disease control. Metam-Na produces a vapor of methylisothiocyanate (MITC) that is lethal to soil organisms including weeds.

Activity of 1,3-D + Pic against nutsedge has been minimal (Gilreath et al., 1994; Locascio et al., 1997; Stall, 1994). Combinations of 1,3-D + Pic with *S*-propyl butyl(ethyl) thiocarbamate (pebulate; Tillam), however, have been efficacious against nutsedge, and 1,3-D + Pic + pebulate is the leading methyl bromide alternative for polyethylene-mulched tomato production (Gilreath et al., 1994; Gilreath et al., 1997; Locascio et al., 1997).

The activity of metam-Na alone on nutsedge has been variable. In one trial, metam-Na provided 88% control when sprayed on flat ground before mixing with soil by false bedding and bed-pressing compared to 23% control when injected into a raised bed (Stall, 1994). Control of nutsedge by metam-Na varied with season (Gilreath et al., 1994) and year (Stall, 1994). Combining pebulate with metam-Na improved nutsedge control compared to that with metam-Na alone (Locascio et al., 1997).

Studies have shown that nutsedge is most susceptible to chemical control when actively growing (Cools and Locascio, 1977; Zandstra and Nishimoto, 1977). This experiment was conducted to test the efficacy of metam-Na and 1,3-D + Pic against yellow nutsedge tubers planted at varying stages of growth and grown in containers.

Materials and Methods

Two greenhouse studies were conducted in Gainesville, Fla. with one study at the Univ. of Fla. campus in spring 2000 and another study at the Horticulture Unit in winter 2001. In spring 2000, there were 22 treatments: two fumigants (1,3-D + 35% Pic at 327 L·ha^{-1} and metam-Na at 294 L·ha^{-1}) and a nonfumigated control, two tuber sources (Gainesville and Quincy), three tuber growth stages (dry, water-imbibed, and sprouted), and metam-Na applied at 147 or 589 L·ha^{-1} to imbibed tubers from each source. Treatments in winter 2001 were the same as those in spring 2000 except only dry and water-imbibed tubers were used. The experimental unit was half of a plastic pan (35.6 cm long × 24.1 cm wide × 15.2 cm deep) with each half containing yellow nutsedge tubers from one source (Gainesville or Quincy); the entire pan received soil with one fumigant treatment and with tubers at one growth stage. Fumigant rates were calculated based on the area of the soil surface of a soil-filled pan. Treatments were replicated six times and arranged in a randomized complete block design.

Quincy tubers ['Chufa' (*Cyperus esculentus* var. sativus)] were kept at 10 °C until they were washed. Tubers obtained from Gainesville were collected on 2 Mar. in spring 2000 and 5 Feb. in winter 2001 at the Horticulture Unit in fields with native and 'Chufa' tubers. On the day Gainesville tubers were collected, tubers from both sources were washed, air-dried at 25 °C, and stored at 10 °C until water-imbibition. Tubers were water-imbibed or sprouted (2.5- to 5-cm- long rhizomes) by

This research was supported by the Florida Agricultural Experiment Station, and approved for publication as Journal Series No. N-02219.
[1]Corresponding author.

keeping them between moist paper towels at 25 °C for approximately 26 h or 1 week, respectively.

Soils (Kanapaha fine sand in spring 2000 and Arredondo fine sand in winter 2001), obtained from the fields where the Gainesville tubers were collected, were screened to remove nutsedge tubers. Treatments were applied 9 Mar. in spring 2000 and 8 Feb. in winter 2001.

All treatments were established using soil that was mixed with water (enough to bring soil to near field capacity) and NH_4NO_3 (at the rate of 112 kg·ha^{-1}) in a cement mixer. Pans were filled with 7.6 cm of soil. Then the nutsedge tubers were planted by evenly distributing them on the soil surface with 20 Gainesville tubers on half of the soil surface in a pan and 20 Quincy tubers on the other half. Tubers were then covered with 6.4 cm of soil. Treatments with no fumigant were established first followed by those with 1,3-D + Pic and then those with metam-Na. The fumigant, 1,3-D + Pic, was applied after covering the planted tubers with soil. A syringe with a hypodermic needle was used to inject the 1,3-D + Pic in equal amounts near the corners of appropriate pans. Metam-Na was applied with the water that was added to the soil in the cement mixer. Immediately after treatment application, each pan was covered with black polyethylene secured by a rubber band and a white pan-lid placed on the polyethylene film.

Pan covers (polyethylene film and pan-lids) were removed 3 d after treatments (DAT). Pans received water as needed via overhead sprinkling with a hose. Nutsedge shoots were counted every 4 d beginning on the day pans were uncovered. Within each replication, nutsedge control with fumigants was calculated by dividing the number of shoots in fumigated pans by that in nonfumigated pans and subtracting the resulting percentage from 100. The experiment was terminated at 28 DAT in spring 2000 and at 44 DAT in winter 2001 when there was no significant increase in nutsedge shoot emergence. Data were analyzed by ANOVA in SAS (SAS, 2000) with tuber sources as main plots.

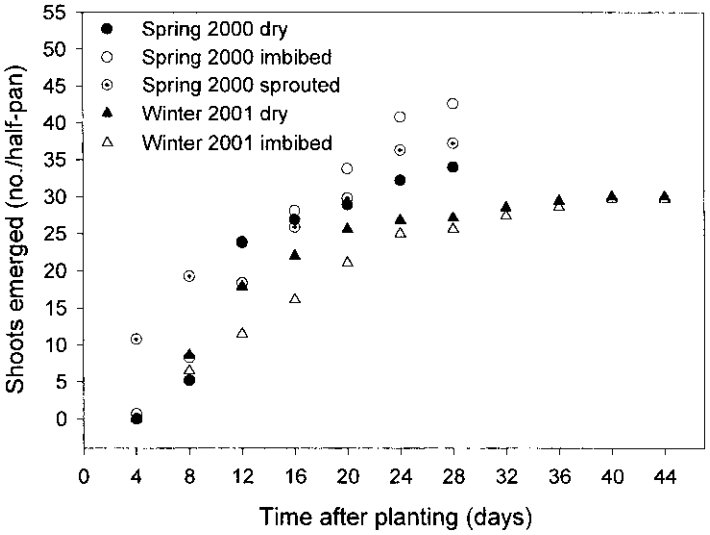

Fig. 1. Cumulative number of emerged yellow nutsedge shoots in nonfumigated soil at 4-day intervals in spring 2000 and winter 2001 from dry, water-imbibed, or sprouted tubers planted in one experimental unit of half a pan. Data for tubers from Gainesville and Quincy were averaged because percentage nutsedge control did not differ between tuber sources.

Results and Discussion

At least 32 and 25 shoots per experimental unit (half of the area of the soil surface in a pan) in spring 2000 and winter 2001, respectively, had emerged in nonfumigated soil by 28 DAT (Fig. 1). These numbers exceeded that of the number of tubers (20) planted in each experimental unit because some tubers produced more than one shoot. Emerged shoots appeared to be evenly distributed in pans. These observations indicated that most or all of the tubers in each season were viable.

Table 1. Main effects of fumigant, yellow nutsedge tuber source, and tuber growth stage on the percentage reduction of yellow nutsedge shoot emergence relative to the number of shoots that emerged through nonfumigated soil. Winter 2001.

		Time after treatment (days)							
		16	20	24	28	32	36	40	44
Treatment	Rate (L·ha^{-1})	Nutsedge control (%)							
Fumigant									
Metam-Na	589	100	100	100	100	100	100	100	100
Metam-Na	147	100	100	100	100	100	100	100	100
Metam-Na	294	100	100	100	100	100	100	100	100
1,3-D + Pic	327	98	97	95	93	93	88	87	86
Signif.		NS	*	NS					
Tuber source									
Gainesville	—	99	99	98	98	98	95	95	94
Quincy	—	99	99	98	97	97	95	95	95
Signif.		NS	NS	NS	NS	NS	NS	NS	NS
Tuber stage									
Dry	—	99	98	96	95	94	90	89	87
Imbibed	—	99	99	99	99	99	99	99	99
Signif.		NS	NS	NS					
Stage × fumigant	—	NS	NS	NS	*	*	*	*	*

NS, *Effects were nonsignificant or significant at $P \leq 0.05$, respectively.

Table 2. Interaction effects of fumigant and tuber growth stage on the percentage reduction of yellow nutsedge shoot emergence relative to the number of shoots that emerged through nonfumigated soil. Winter 2001.

Treatment combinations[z]			Time after treatment (days)				
			28	32	36	40	44
Fumigant	Rate ($L \cdot ha^{-1}$)	Tuber stage	Nutsedge control (%)				
Metam-Na	294	Dry	100 a	100 a	100 a	100 a	100 a
Metam-Na	294	Imbibed	100 a	100 a	100 a	100 a	100 a
Metam-Na	589	Imbibed	100 a	100 a	100 a	100 a	100 a
Metam-Na	147	Imbibed	100 a	100 a	100 a	100 a	100 a
1,3-D + Pic	327	Imbibed	98 a	98 a	97 a	97 a	97 a
1,3-D+Pic	327	Dry	89 b	89 b	80 b	77 b	75 b
		Signif.	**	**	***	***	***

**, ***Column effects were significant at $P \leq 0.01$ or 0.001, respectively. Means within columns followed by the same letter are similar at $P \leq 0.05$ according to Duncan's multiple range test.

[z]Each treatment combination was a discrete treatment.

In spring 2000, tubers in 1,3-D + Pic- or metam-Na-treated soil failed to sprout by 28 DAT. Therefore, both fumigants provided 100% control of yellow nutsedge in spring 2000 for 28 DAT. Data obtained in spring 2000 were not analyzed and presented because of the complete uniformity in percentage nutsedge control.

In winter 2001, 100% nutsedge control was obtained with metam-Na during the 44-d duration of the experiment; however a few shoots had emerged through soil treated with 1,3-D + Pic at 16 DAT. At 20 DAT, the percentage of nutsedge control obtained with metam-Na (100%) exceeded that with 1,3-D + Pic (97%) (Table 1). Tuber source had no influence on nutsedge control (%) with 1,3-D + Pic and metam-Na. Tuber growth stage had no affect on nutsedge control (%) at 16, 20, and 24 DAT.

Tuber growth stage interacted with fumigant on percentage nutsedge control at and after 28 DAT in winter 2001 (Table 1). Metam-Na provided 100% nutsedge control regardless of rate or tuber growth stage (Table 2). The fumigant, 1,3-D + Pic, provided similar nutsedge control as metam-Na when applied to tubers that were imbibed before planting; however, 1,3-D + Pic provided 9% (at 28 DAT) to 22% (at 44 DAT) greater nutsedge control when tubers were imbibed than dry at fumigation time.

The activity of 1,3-D is likely determined by factors at and shortly after application. Ajwa and Trout (2000) found that concentrations of 1,3-D in soil gas after chemigation were highest at 24 to 36 h and undetectable at 14 DAT. In the present study, early-morning air temperature on the day 1,3-D + Pic was applied was 12 °C in spring 2000 compared to 4 °C in winter 2001. Therefore, soil temperatures when 1,3-D + Pic was applied (by 12:00 PM) were probably higher in spring 2000 than winter 2001. This may account for greater activity of 1,3-D + Pic in spring 2000 than in winter 2001 because the diffusion of fumigant gas increases with increased temperature (McKenry and Thomason, 1974). Total nutsedge control with metam-Na in both seasons indicated that metam-Na affected nutsedge activity over a broader temperature range than 1,3-D + Pic.

Greater activity of 1,3-D + Pic in winter 2001 against imbibed than dry tubers (Table 2) was expected because soil fumigants are most toxic to organisms that are biologically active (A. J. Overman, University of Florida, pers. comm.). The first shoots to emerge through nonfumigated soil in winter 2001 (between 4 and 8 DAT) were those from tubers that were water-imbibed before planting. Therefore, at 1,3-D + Pic application time, tubers imbibed before planting were probably more biologically active and susceptible to 1,3-D + Pic than tubers planted dry. Similarly, glyphosate controlled purple nutsedge most effectively during seasons when nutsedge tubers sprouted the most rapidly (Cools and Locascio, 1977). Irrigating the soil before fumigating may maximize the biological activity and subsequent susceptibility of nutsedge tubers to 1,3-D + Pic.

Total or near total control of yellow nutsedge for 1 month with both fumigants, regardless of tuber growth stage, contrasted with results of field studies where 1,3-D + Pic and metam-Na provided erratic or poor nutsedge activity (Gilreath et al., 1994; Locascio et al., 1997; Stall, 1994). The strong activity of metam-Na and 1,3-D + Pic against nutsedge in this experiment was likely due to minimal fumigant outgassing. There were no holes in the pans, and pans were covered with nonperforated polyethylene film and pan-lids during the first 3 DAT.

It may be possible to enhance the effectiveness of metam-Na and 1,3-D + Pic by adopting production practices such as the use of virtually impervious film (VIF) to minimize volatilization of fumigant gasses. Ajwa and Trout (2000) found that concentrations of 1,3-D in soil gas at 24 h after application were at least 40% greater under VIF than standard polyethylene film. Locascio and Dickson (2001), however, found that VIF did not improve nutsedge control with 1,3-D + Pic (17%) relative to standard polyethylene film. Their results also indicated that higher fumigant concentrations in the bed with VIF compared with standard film may have resulted in crop injury. More research is needed to optimize performance of metam-Na and 1,3-D + Pic with products such as VIF without inducing crop injury.

Literature Cited

Ajwa, H. and T. Trout. 2000. Distribution of drip applied fumigants under various conditions, p. 59. In Proc. Annu. Intl. Res. Conf. on Methyl Bromide Alternatives and Emissions Reductions.

Buker, R. S. 1999. Interference of yellow nutsedge with watermelon. MS Thesis, Horticultural Sciences Dept., University of Florida, Gainesville.

Cools, W. G. and S. J. Locascio. 1977. Control of purple nutsedge (*Cyperus rotundus* L.) as influenced by season of application of glyphosate and nitrogen rate. Proc. South. Weed Sci. Soc. 30:158-164.

Environmental Protection Agency. 1999. Protection of stratospheric ozone: Incorporation of Montreal protocol adjustment for a 1999 interim reduction in Class I, Group VI controlled substances. Federal Register 64:29240-29245.
Gilreath, J. P., J. P. Jones, and A. J. Overman. 1994. Soil-borne pest control in mulched tomato with alternatives to methyl bromide. Proc. Fla. State Hort. Soc. 107:156-159.
Gilreath, J. P., J. W. Noling, P. R. Gilreath, and J. P. Jones. 1997. Field validation of 1,3 dichloropropene + chloropicrin and pebulate as an alternative to methyl bromide in tomato. Proc. Fla. State. Hort. Soc. 110:273-276.
Locascio, S. J. and D. W. Dickson. 2001. Alternative fumigants applied with PE and VIF mulches for tomato, p. 17. In Proc. Annu. Intl. Res. Conf. on Methyl Bromide Alternatives and Emissions Reductions.
Locascio, S. J., J. P. Gilreath, D. W. Dickson, T. A. Kucharek, J. P. Jones, and J. W. Noling. 1997. Fumigant alternatives to methyl bromide for polyethylene-mulched tomato. HortScience 32:1208-1211.
McKenry, M. V. and I. J. Thomason. 1974. 1,3-dichloropropene and 1,2-dibromoethane compounds: I. Movement and fate as affected by various conditions in several soils. Hilgardia 42:393-421.
Morales-Payan, J. P., W. M. Stall, D. G. Shilling, J. A. Dusky, and T. A. Bewick. 1997. Influence of nitrogen on the interference of purple and yellow nutsedge *(Cyperus rotundus* and *Cyperus esculentus*) with tomato (*Lycopersicon esculentum*) HortScience 32:431 (Abstr.).
Motis, T. N., S. J. Locascio, and J. P. Gilreath. 2001. Yellow nutsedge interference effects on fruit weight of polyethylene-mulched bell pepper. Proc. Fla. State Hort. Sci. 114:268-271.
Overman, A. J. and F. G. Martin. 1978. A survey of soil and crop management practices in the Florida tomato industry. Proc. Fla. State Hort. Soc. 91:294-297.
SAS Institute. 2000. Proprietary software release 8.1. SAS Inst., Cary, N.C.
Stall, W. M. 1994. Effect of integrating alternative fumigant rates and methods with herbicides on nutsedge control, p. 12. In Proc. Annu. Intl. Res. Conf. on Methyl Bromide Alternatives and Emissions Reductions.
Thullen, R. J. and P. E. Keeley. 1975. Yellow nutsedge sprouting and resprouting potential. Weed Sci. 23:333-337.
Zandstra, B. H. and R. K. Nishimoto. 1977. Movement and activity of glyphosate in purple nutsedge. Weed Sci. 25:268-274.