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Effects of Water Delivery Volume, Rates and Concentrations of Metam Potassium on Purple Nutsedge Emergence in Mulched Beds

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SUMMARY. Over the years, efficacy of metam potassium (MK) on purple nutsedge (*Cyperus rotundus*) control has been inconsistent, in many cases because of a lack of knowledge about application techniques. Therefore, field studies were conducted to determine the effect of water delivery volumes and flow rates on purple nutsedge control with MK, and the influence of MK rates and concentrations on purple nutsedge control. Three separate studies were established for 1) water application volumes and flow rates, 2) MK application rates and concentrations, and 3) MK concentration levels. For the water application volumes and flow rate trials, a single MK rate of 60 gal/acre was injected with either 1 or 2 acre-inch/acre (27,154 or 54,308 gal/acre) of water. The water flow rates were 0.30, 0.45, and 0.60 gal/100 ft of row per minute within each water volume. An nontreated control was included. In the application rate and concentrations studies, treatments were a nontreated control, 30 gal/acre applied with 0.5 acre-inch/acre of water (≈3000 ppm), 60 gal/acre applied with either 0.5 or 1 acre-inch/acre of water (≈6000 and 3000 ppm), 120 gal/acre applied with either 1 or 2 acre-inch/acre of water (≈6000 and 3000 ppm), and 240 gal/acre applied with 2 acre-inch/acre of water (≈6000 ppm). In the MK concentration trials, 0, 2000, 3000, 4000, 5000, and 6000 ppm were tested. Results indicated that neither water volumes nor flow rates used for MK application had a significant impact on purple nutsedge control at 10 weeks after treatment (WAT). However, there was a significant effect of the combinations of MK rates and water delivery volumes on purple nutsedge densities at 4 and 15 WAT. Similarly, MK concentrations obtained from a single application rate resulted in improved purple nutsedge control up to 10 WAT, reducing densities to less than 5 plants/ft^2 with 6000 ppm of MK.

The search for methyl bromide (MBr) alternatives has been a vast source of research during the last decade, in which hundreds of trials have been conducted nationwide to examine the efficacy of different soil fumigants on soil-borne pests in polyethylene-mulched tomato (*Lycopersicon esculentum*), pepper (*Capsicum annuum*), strawberry (*Fragaria ×ananassa*), cucurbits, cut flowers, and other commodities. Although a great deal of progress has been achieved in this field, currently there is no a single molecule to replace MBr. Instead, ongoing research focuses not only on the efficacy of the combination of certain fumigants and herbicides, but also on application techniques and formulations (Duerksen, 2002; Noling and Gilreath, 2001). Purple nutsedge and yellow nutsedge (*Cyperus esculentus*) are the most troublesome weeds to control in polyethylene-mulched vegetable crops and have the ability to emerge through the mulch, causing yield and quality losses (Gilreath and Santos, 2005; Gilreath et al., 2005). In the past, MBr applications have effectively reduced nutsedge populations below damage thresholds. However, other fumigants do not have consistent efficacy against these weeds.

Metam sodium and metam potassium (MK) are among the most promising MBr alternatives (Ajwa et al., 2002; Martin, 2003). The primary breakdown product of these fumigants is methyl isothiocyanate, which is a potent biocide that react with amines and thiols in biological molecules (Duniway, 2002; Lam et al., 1993; Pruett et al., 2001). These fumigants are available in liquid formulations, which provide application flexibility because they can be either directly sprayed on the soil or drip injected (Duniway, 2002; Ou et al., 2006). The efficacy of these fumigants against nutsedge has been tested with mixed results (Ajwa et al., 2003; Martin, 2003). Previous research showed that metam efficacy against nutsedges increases when partnered with preemergence herbicides in tomato (Gilreath and Santos, 2004a, c). In contrast, Locascio et al. (1997), examining the effect on tomato yield of two forms of application of metam in comparison with MBr plus chloropicrin (Pic), found that fruit yield in the drip-applied metam plots was ≈60% of that for MBr + Pic, whereas the performance of the soil-applied metam was even lower.

Recently, various reports have suggested improved MK performance on nutsedges (Vaculin et al., 2003). However, MK rates, distribution in the soil, water delivery volumes, and flow rates could be among the reasons for the inconsistent results. Duniway (2002) suggested that metam must be delivered carefully to avoid either leaching, when excessive water volumes are used, or rapid volatilization, with application of insufficient water. Ou et al. (2006) indicated that water volumes play a significant role in the distribution of metam within the first 8 inches of the soil. However, further characterization of the influence of water volumes is needed to provide definite answers on its role on

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Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
254.0000	acre-inch/acre	$m^3 \cdot ha^{-1}$	0.0039
0.0929	ft^2	m^2	10.7639
0.1242	gal/100 ft	$L \cdot m^{-1}$	8.0520
9.3540	gal/acre	$L \cdot ha^{-1}$	0.1069
2.5400	inch(es)	cm	0.3937
0.0254	mil	mm	39.3701
1	ppm	$\mu L \cdot L^{-1}$	1

weed control. Therefore, the objectives of these studies were to determine: 1) the effect of water delivery volumes and flow rates on purple nutsedge control with MK, and 2) the influence of MK rates and concentrations on purple nutsedge control.

Materials and methods

WATER APPLICATION VOLUMES AND FLOW RATES. Research plots were established at the University of Florida Gulf Coast Research and Education Center in Bradenton (GCREC) during Fall 2002 and Spring 2003. The soil was an EauGallie fine sand (Alfic Haplaquods, sandy, siliceous, hyperthermic) with 1.0% organic matter and a pH of 7.3. Selected fields were heavily infested with purple nutsedge (≈15 plants/ft²). For these trials, 8-inch-tall × 28-inch-wide beds were pressed and covered with low-density polyethylene mulch (1.25 mil thick; Pliant Corp., Schaumburg, Ill.). Two drip irrigation lines (T-Tape Systems, San Diego) were buried 1-inch deep in the bed center under the mulch film. Irrigation emitters were 12 inches apart. Besides drip irrigation, continuous subsurface irrigation maintained the water table at 18 inches deep to reduce water stress on weed populations.

A single MK rate of 60 gal/acre was injected with either 1 acre-inch/acre (≈3000 ppm) or 2 acre-inch/acre (≈1500 ppm) of water. The water flow rates were 0.30, 0.45, and 0.60 gal/100 ft of row per minute within each water volume. A nontreated control was included. Metam potassium was injected with electric water pumps, which were connected to mixing tanks where the solutions were prepared and constantly agitated. These treatments were arranged in a randomized complete block design with five replications. Purple nutsedge was counted at 2, 10, and 15 weeks after treatment (WAT) over the entire experimental area. Because of a lack of normality and homogeneity of variances, purple nutsedge ranked means were analyzed with the Friedman nonparametric test (P = 0.05). Individual and grouped treatment means were compared with single-df orthogonal contrasts (P = 0.05; SAS Institute, Cary, N.C.).

METAM POTASSIUM APPLICATION RATES AND CONCENTRATIONS. Field trials at the GCREC were carried out during Fall 2003 and Spring 2004 in a similar fashion described earlier. Application rates were 1) 30 gal/acre applied with 0.5 acre-inch/acre of water (≈3000 ppm), 2) 60 gal/acre applied with 1 acre-inch/acre of water (≈3000 ppm), 3) 60 gal/acre applied with 0.5 acre-inch/acre of water (≈6000 ppm), 4) 120 gal/acre applied with 2 acre-inch/acre of water (≈3000 ppm), 5) 120 gal/acre applied with 1 acre-inch/acre of water (≈6000 ppm), and 6) 240 gal/acre applied with 2 acre-inch/acre of water (≈6000 ppm). A nontreated control was included. Although some of these MK rates are higher than the labeled rates, their use allows drawing conclusions about the influence of rates and water volumes on MK concentrations. Treatments were arranged in a randomized complete block design with five replications. Purple nutsedge was counted at 4 and 10 WAT over the entire experimental area. This variable was analyzed with the same statistical procedure described previously.

METAM POTASSIUM CONCENTRATION LEVELS. The effect of MK concentrations on purple nutsedge growth was assessed during Fall 2003 and Spring 2004 with similar field methodology as explained earlier. The applied MK concentrations were 2000, 3000, 4000, 5000, and 6000 ppm, and these were obtained by mixing a single rate of 120 gal/acre with 3, 2, 1.5, 1.2, and 1 acre-inch/acre of water respectively. A nontreated control was added. Purple nutsedge densities were determined at 4, 6, and 10 WAT. Purple nutsedge responses to MK concentrations were characterized with regression analysis, and comparisons between individual means were examined with single-df orthogonal contrasts (P = 0.05; SAS Institute).

Results and discussion

WATER APPLICATION VOLUMES AND FLOW RATES. There were no significant treatment-by-season interactions ($P > 0.05$) for purple nutsedge densities at 2 and 10 WAT. Thus, data from both seasons were combined for analysis and interpretation. At 2 WAT, the addition of MK reduced purple nutsedge populations in comparison with the nontreated control (Table 1). The purple nutsedge density in the control plot was 14.4 plants/ft², and in the MK-treated plots weed densities ranged between 2.4 and 5.1 plants/ft², with no differential effect of specific combinations of water flow rates and volumes on purple nutsedge densities. Metam potassium treatments had no effect on purple nutsedge control at 10 WAT, with densities ranging between 24.3 and 39.7 plants/ft², which were not different from the nontreated control. Therefore, these water flow rates and volumes did not improve MK activity against purple nutsedge.

METAM POTASSIUM APPLICATION RATES AND CONCENTRATIONS. Season-by-treatment interactions were not significant for purple nutsedge densities at 4 and 15 WAT. Therefore, data from two trials were combined for analysis. During the first observation, each MK treatment reduced purple nutsedge populations, regardless of rates and water volumes (Table 2). The nontreated control had a purple nutsedge density of 4.5 plants/ft², and the average density in the MK-treated plots was ≈0.2 plants/ft². At this time, treatments applied with 6000 ppm of MK showed significantly higher purple nutsedge control than with 3000 ppm of MK, regardless of water volume and fumigant rate. However, there were no significant effects when these concentrations were compared within each MK rate.

At 15 WAT, MK treatments remained more effective on purple nutsedge populations than the nontreated control. However, the efficacy against the weed changed dramatically among fumigant rates. Metam potassium treatments with application concentrations of 3000 ppm averaged 11.9 plants/ft², whereas those that received 6000 ppm had 4.2 purple nutsedge plants/ft². Within both 60 and 120 gal/acre, the fumigant was more effective controlling nutsedge with 6000 ppm (6.7 and 3.8 plants/ft² respectively) than with 3000 ppm (14.3 and 6.4 plants/ft²), indicating that concentration was a major factor in purple nutsedge control with MK. However, although concentrations of MK had an effect on purple nutsedge densities, these concentrations were the result of different combinations or application rates and water delivery volumes,

Table 1. Influence of water volumes and drip line flow levels on purple nutsedge densities with metam potassium at Bradenton, Fla., 2002–2003.

Fumigant	Water flow rate, (gal/100 ft/min)[z]	Water volume (acre-inch/acre)	Purple nutsedge density (plants/ft²)[y] 2 WAT	Purple nutsedge density (plants/ft²)[y] 10 WAT
Nontreated control	—	—	14.4	24.8
Metam potassium	0.30	1	2.7	26.0
Metam potassium	0.45	1	2.7	39.7
Metam potassium	0.60	1	5.1	32.7
Metam potassium	0.30	2	4.8	34.8
Metam potassium	0.45	2	2.4	24.3
Metam potassium	0.60	2	3.6	26.4
Single-df orthogonal contrasts				
Control vs. metam potassium			*	NS
1 vs. 2 acre-inch water			NS	NS
0.30 vs. 0.45 gal/100 ft/min			NS	NS
0.30 vs. 0.60 gal/100 ft/min			NS	NS
0.45 vs. 0.60 gal/100 ft/min			NS	NS

[z]1 gal/100 ft = 0.1242 $L \cdot m^{-1}$, 1 acre-inch/acre = 254 $m^3 \cdot ha^{-1}$, 1 plant/ft² = 10.7639 plants/m².
[y]Purple nutsedge density data from two seasons were combined, and ranked means were analyzed with the Friedman nonparametric test ($P \leq 0.05$). Individual and grouped treatment means were compared with single-df orthogonal contrasts ($P \leq 0.05$).
WAT, weeks after treatment.
NS,*Nonsignificant or significant at $P = 0.05$.

which might confound conclusions. Therefore, a study with varying MK concentrations obtained from a single fumigant rate would provide definite confirmation of the concentration effect on purple nutsedge densities.

Metam potassium concentration levels. There were significant effects of MK concentrations on purple nutsedge densities at 4, 6, and 10 WAT. At 4 WAT, purple nutsedge densities decreased exponentially as MK concentrations increased, with a maximum weed density of 11.6 plants/ft² when no fumigant was applied and declining to 3.5 and 1.0 plants/ft² when MK concentrations reached 3000 and 6000 ppm respectively (Fig. 1). Two weeks later, the same exponential relationship between MK concentration and purple nutsedge densities persisted. However, in the nonfumigated control, weed density reached 22.5 plants/ft², and decreased to 9.2 and 3.7 plants/ft² with 3000 and 6000 ppm respectively (Fig. 1). A linear regression model characterized the purple nutsedge density response to applied concentrations of MK at 10 WAT. Based on the predicted values of the equation, a purple nutsedge density of 29.1 plants/ft² would be expected with no fumigation, whereas adding 3000 and 6000 ppm of MK would decrease the weed population to 16.8 and 4.5 plants/ft² (42% and 85% nutsedge control respectively).

Previous studies on purple nutsedge interference in vegetable crops have shown that a density of 5 plants/ft² causes relatively marginal yield reductions in tomato and pepper (Morales-Payan et al., 1997), whereas a nutsedge density of more than 10 plants/ft² can reduce tomato yield by 51% (Gilreath and Santos, 2004b).

Table 2. Effect of water application volumes, and metam potassium rates and concentrations on purple nutsedge densities with metam potassium at Bradenton, Fla., 2003–2004.

Fumigant	Rate (gal/acre)[z]	Water volume (acre-inch/acre)	Concn (ppm)	Purple nutsedge density (plants/ft²)[x] 4 WAT	Purple nutsedge density (plants/ft²)[x] 15 WAT
Nontreated control	—	—	—	4.5	20.0
Metam potassium	30	0.5	3000	0.8	14.9
Metam potassium	60	1	3000	0.2	14.3
Metam potassium	60	0.5	6000	0.1	6.7
Metam potassium	120	2	3000	0.2	6.4
Metam potassium	120	1	6000	0.1	3.8
Metam potassium	240	2	6000	0	2.1
Single-df orthogonal contrasts					
Control vs. metam potassium				*	*
3000 vs. 6000 ppm				*	*
3000 vs. 6000 ppm with 60 gal/acre				NS	*
3000 vs. 6000 ppm with 120 gal/acre				NS	*

[z]1 gal/acre = 9.3540 $L \cdot ha^{-1}$, 1 acre-inch/acre = 254 $m^3 \cdot ha^{-1}$, 1 ppm = 1 $mL \cdot L^{-1}$, 1 plant/ft² = 10.7639 plants/m².
[y]Purple nutsedge density data from two seasons were combined, and ranked means were analyzed with the Friedman nonparametric test ($P \leq 0.05$). Individual and grouped treatment means were compared with single-df orthogonal contrasts ($P \leq 0.05$).
WAT, weeks after treatment.
NS,*Nonsignificant or significant at $P = 0.05$.

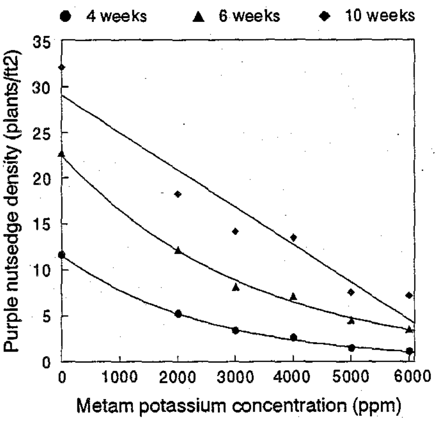

Fig. 1. Effects of metam potassium concentrations on purple nutsedge densities at 4, 6, and 10 weeks after treatment. Regression equations are $y = 11.6e^{(-0.0004x)}$ for 4 weeks, $y = 22.5e^{(-0.0003x)}$ for 6 weeks, and $y = 29.1 - 0.0041x$ for 10 weeks after treatment. All r^2 values were ≥ 90%; 1 ppm = 1 $mL \cdot L^{-1}$, 1 plant/ft² = 10.7639 plants/m².

In the current study, application of MK decreased purple nutsedge populations, resulting in densities less than 5 plants/ft² with 6000 ppm for up to 10 WAT. However, this concentration can be achieved with an MK rate of 60 gal/acre dissolved in 0.5 acre-inch/acre of water, which is within the recommended rates in the label of the commercial formulation of the product. The results indicated that with the appropriate MK concentrations and uniform delivery throughout planting beds, it is likely to cause longer and more effective exposure of purple nutsedge tubers and other underground structures to the fumigant, thus increasing its efficacy.

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