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Potential effects of diurnally alternating temperatures and solarization on purple nutsedge (*Cyperus rotundus*) tuber sprouting

I.S. Travlos [a,*], G. Economou [b,1], V.E. Kotoulas [b,2], P.J. Kanatas [b,3], A.N. Kontogeorgos [c,4], A.I. Karamanos [b,2]

[a] *Benaki Phytopathological Institute, Department of Weed Science, Laboratory of Integrated Weed Management and Plant Growth Regulators, 8 St. Delta street, GR-145 61 Kifissia, Athens, Greece*
[b] *Agricultural University of Athens, Department of Crop Production, Laboratory of Agronomy, 75, Iera Odos st., 11855 Athens, Greece*
[c] *Aristotle University of Thessaloniki, Department of Agricultural Economics and Policy, School of Agriculture, 541 24 Thessaloniki, Greece*

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ABSTRACT

Purple nutsedge (*Cyperus rotundus* L.) is one of the most serious weed problems of the arid environments. The distribution of its tubers in a naturally infested field in Greece indicated that the highest proportion is located in the upper 200 mm of the soil. Furthermore, the effects of temperature alternation on the rate and percentage of tuber sprouting were evaluated by means of laboratory studies. It was found that the total tuber sprouting and rate were significantly increased after a shift of daily temperature fluctuation from 0 to 12 °C. Sprouting rate and percentage were significantly and consistently higher for the tubers originating from the upper 5 cm of the soil, compared with the tubers obtained from the layer of 50–150 mm for all the temperature treatments. Additionally, solarization seems potentially effective on purple nutsedge tuber sprouting, as long as it resulted not only to a soil temperature shift, but also to a high diurnal temperature variation. Moreover, the uniform sprouting of about 95% of the tubers in the soil may allow a more complete control by mechanical, biological or chemical methods.

1. Introduction

Purple nutsedge (*Cyperus rotundus* L.) has been reported to be troublesome in more countries, regions and localities than any other weed in the world, including many arid and semiarid regions (Holm et al., 1991). This species causes yield losses higher than 30% in a wide variety of crops (Keeley, 1987; Stoller and Sweet, 1987). It propagates almost exclusively by vegetative means (basal bulbs, tubers and rhizomes) and therefore mechanical or hand weeding operations are only partially successful in reducing its competitiveness (Bendixen and Nandihalli, 1987). The fast-growing nature, the high viability and the rapid development of vegetative structures for reproduction explain the aggressiveness of this species, allowing it to survive even under stress conditions (Williams, 1982; Nishimoto, 2001). Moreover, *C. rotundus* is one of the most common weeds of the secondary succession occurring in abandoned and dry fields of arid environments (El-Sheikh, 2005), while Greece is among the countries with the highest percent winter survival of purple nutsedge (Wills, 1998), resulting to an even more difficult control.

The ability to promote uniform tuber sprouting is crucial for the control of this weed, while a small percentage of surviving tubers can rapidly result to a serious weed problem (Horowitz, 1972; Webster, 2005). In spite of the numerous studies of the effects of constant temperatures on tuber sprouting, little is known about the effect of alternating temperatures. Only Miles et al. (1996) have suggested that daily alternating temperatures could be an important factor for tuber sprouting. The combination of tillage operations that sever rhizome chains release apical dominance, solarization that promotes nutsedge emergence and systemic herbicides to control emerged foliage, may improve nutsedge management (Miles et al., 2002). Therefore, it is important to know the distribution of tuber population in the soil. For this reason, the objectives of this study were to determine: a) the effect of several

* Corresponding author. Tel.: +3 210 8180374; fax: +3 210 8087506.
E-mail addresses: htravlos@in.gr (I.S. Travlos), economou@aua.gr (G. Economou), vaskwt@yahoo.com (V.E. Kotoulas), pakanatas@yahoo.gr (P.J. Kanatas), akontogeorgos@yahoo.gr (A.N. Kontogeorgos), akaram@auadec.aua.gr (A.I. Karamanos).
[1] Tel.: +3 210 529 4756; fax: +3 210 529 4482.
[2] Tel.: +3 210 529 4492; fax: +3 210 529 4482.
[3] Tel./fax: +3 210 529 4482.
[4] Tel./fax: +3 2310 760218.

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diurnally alternating temperatures and temperature amplitudes on tuber sprouting from several soil depths and b) the potential effects of solarization on the stimulation of tuber sprouting by arrangement of the daily temperature obtained in the soil.

2. Materials and methods

2.1. Experimental details

The experiments were conducted at one of the research farms of the Agricultural University of Athens (AUA), Greece (latitude 37° 58′ N; longitude 23° 32′ E). The soil was clay loam (CL 0–25 cm; 34.6% clay, 27.7% silt and 37.7% sand), calcareous (13.3% $CaCO_3$), with a pH value of 7.17 and relatively moderate organic matter (determined according to Wakley and Black, 1934) and nitrogen content (1.87 and 13.5%, respectively), with sufficient levels of nitrate and available phosphorus, rich in available potassium and sodium (94.3, 17.95, 600 and 110 ppm, respectively) and with high levels of cation exchange capacity (4990 ppm). The previous crop was groundnut (*Arachis hypogaea* L.).

A field, infested with purple nutsedge, was irrigated twice weekly with 10 mm water each time. Soil samples were collected on the same day at ten randomly selected points in the field. The samples were taken from the upper 0–300 mm of soil using a cylindrical auger (300 mm length, 100 mm diameter). The soil samples were cut horizontally at depth intervals of 50 mm within the 0–300 mm layer. These slices were washed to expose the tubers, which were collected, trimmed of roots and rhizomes and submerged in water for 24 h to obtain homogeneous imbibition (room temperatures). Tuber number, fresh and dry weight (85 °C for five days) were recorded.

Two sprouting experiments were conducted in the Laboratory of Agronomy of AUA. Both tests were carried out in a completely randomized design under laboratory conditions, in incubators at total darkness. The first laboratory experiment was designed to compare sprouting at four diurnally alternating temperature regimes (18/22, 26/30, 34/38 and 42/46 °C, 12 h each) for tubers of fresh weight ranging from 0.5 to 2 g, originating from two soil depths (0–50 and 50–150 mm). Previously, tuber viability was verified by means of a preliminary sprouting test of a randomly selected pool of 100 tubers of all sizes and soil depths. No selection was made on the basis of colour (and maturity), but any tubers with physical damage, or which were soft, rotten, or otherwise clearly not viable were discarded. Tubers sprouted in Petri dishes (90 mm in diameter) on two layers of filter paper were moistened with deionized water. Each treatment consisted of five dishes of 20 tubers. Dishes were stacked, enclosed in a clear 0.028 mm polyethylene bag to conserve moisture, and kept on the lab bench overnight at approximately 20 °C. Tubers were counted as sprouted when at least one shoot reached 10 mm in length (Miles et al., 1996). Sprouted tubers were counted and removed daily for 20 days (end of incubation period). Tuber sprouting rate was determined by taking the reciprocal of the time (d) to 50% sprouting, e.g. Reciprocal Median Response Time or d^{-1} (Scott et al., 1984) and total percent sprouting was also measured.

The second laboratory experiment was conducted to determine the effect of the magnitude of the temperature amplitude on purple nutsedge tuber sprouting. The treatments consisted of the same daily mean temperature (32 °C), arising from four several daily alternating temperatures (32/32, 30/34, 28/36 and 26/38 °C, 12 h each). The plant material and the experimental procedure were the same with the first sprouting experiment. Daily measurements of sprouted tubers were taken during all the incubation period (20 days), in order to calculate tuber sprouting rate and total sprouting percentage.

Additionally, in order to investigate the effects of soil solarization on soil temperatures, an experiment was also conducted in a part of the above-mentioned field, in 2003 and 2004, for 4 weeks. Soil solarization is the process of heating soils under transparent plastic tarps to temperatures detrimental to soilborne pests, including weed seeds (Stapleton and DeVay, 1986). Our solarization experiment included two treatments, solarized and nonsolarized, arranged in a completely randomized design with four replications. Transparent polyethylene (PE) colorless sheets (Plastica of Crete S.A., Heraklio, Crete, Greece), 0.05 mm thick, were used to cover the plots (plot size was 2 m long by 2 m wide), while the soil was previously ploughed, leveled and irrigated to field capacity. The PE covering was buried along the edges in a 200-mm-deep furrow. Non-covered plots of the same size were similarly tilled and watered. Soil temperatures at 50 and 150 mm for both solarized and control plots, were monitored every 20 min with thermistor sensors (NTC thermistor, UTECO ABEE, Athens, Greece), buried in the center of the plots and averages were recorded hourly by a data logger (DL2e, Delta-T Devices Ltd 128 Low Road Burwell, Cambridge, CB5 OEJ, UK).

2.2. Statistical analysis

Homogeneity of variance was evaluated before data analysis. The percentages of sprouting (after angular transformation) and the rest raw data were subjected to ANOVA using the Statgraphics statistical software package (v.5.0, Statistical Graphics Corporation, Englewood Cliffs, NJ, USA). Mean comparison was performed using Fisher's least significant difference (LSD) method ($p < 0.05$).

3. Results

In our field, the number of tubers declined with increasing soil depth (Table 1). The number of tubers in soil to a depth of 300 mm was characterized by the following equation: $y = 0.475x^2 - 27.014x + 383.3$, where y represents the number of tubers in the soil at depth x ($r^2 = 0.98$, $p < 0.001$).

The cumulative tuber populations in the upper 50, 100, 150, 200, 250 and 300 mm of soil were 45, 79, 94, 97, 99 and 100%, respectively. It is clear by the above-mentioned equation that the number of tubers (and the percentage of total population) was significantly affected by soil depth (tuber population was significantly higher in the soil depths of 0–50 and 50–100 mm).

Tuber fresh and dry weight increased significantly with soil depth. It is interesting to note that purple nutsedge tuber density was negatively correlated with their fresh ($r^2 = -0.99$, $p < 0.001$) and dry weight ($r^2 = -0.99$, $p < 0.001$).

The sprouting rate and percentage were consistently highest for the 34/38 °C treatment and lowest for the 18/22 °C treatment. The 26/30 and 42/46 °C regimes exhibited intermediate values of sprouting percentage and rate.

Table 1
Distribution of *C. rotundus* tubers in several soil depths.

Soil depth (mm)	Tubers collected (%)	Tuber dry weight (g)
0–50	45 ± 5*a*	0.12 ± 0.04*b*
50–100	34 ± 3*a*	0.17 ± 0.03*b*
100–150	15 ± 3*b*	0.24 ± 0.5*a*
150–200	3 ± 2*b*	0.26 ± 0.04*a*
200–250	2 ± 1*b*	0.28 ± 0.01*a*
250–300	1 ± 0*b*	0.28 ± 0.03*a*

Tubers collected and tuber weights are means of the totally collected tubers on each one of the six replications. Standard deviations are also shown. Values followed by different case letters in columns are significantly different ($p < 0.05$) according to Fischer's LSD test.