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Evaluation of Integrated Control Methods of Purple Nutsedge (*Cyperus rotundus* L.) In Transplanted Onion

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ABSTRACT

Onion (*Allium cepa* L.) is one of the most important vegetable crops in the world. Weeds are the most global problem in onion production. Purple nutsedge (*Cyperus rotundus* L.) is one of the most damaging weeds, which propagates rapidly through extensive underground system and tubers. The aims of this study were to evaluate the effect of solarization duration and tuber weight on characters of *C. rotundus* and assessed different treatments on the weed control and onion yield. For this purpose, two separate experiments were conducted in South of Kerman Agricultural Research and Education Center, Jiroft, Iran. The solarization experiment conducted to investigate the effects of solarization duration [0 (control), 5, 10, 15, and 20 days] and tuber weight (small, medium and large) on tuber viability and the number

of produced tubers of *C. rotundus*. The weed management experiment conducted as a randomized complete block design with eight weed management methods with three replications. The results of the solarization experiment showed that in all solarization duration tuber viability eliminated except for control. The maximum percentage of tuber viability found in the interaction of non-solarization with large and medium tuber weights. Also, the results of the weed management experiment revealed that after hand plucking treatment, deep disking twice with 20 days interval followed by application of Glyphosate twice after each disk treatment (T8) was the best weed management method. The highest onion yield was obtained in hand plucking and T8 treatments by 96.53 and 70.67 ton ha⁻¹, respectively.

Keywords: Solarization; Purple nutsedge; Onion; Tuber weight; Glyphosate

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1. Introduction

Onion (*Allium cepa* L.) is one of the most important vegetable crops in the world. It belongs to Magnoliophyta division, Liliopsida class, Liliales order, and Liliaceae family. Weeds are the most global problem to onion production and reduced it to 70-75% (Mani & Gautam 1976; Chattopadhyay et al 2016). There are many different weeds associated with this plant such as purple and yellow nutsedges, cockspur grass, feverfew, gooseberry and common purslane (Sahu et al 2017; Sahu et al 2018).

Purple nutsedge (*Cyperus rotundus* L.) is one of the most important weeds and a perennial sedge which propagates rapidly through extensive underground system and tubers (Nelson & Renner 2002). Also, it has a high ability to compete with other plants as well as to survive in different conditions. This weed grows in some regions of Iran that

possess fertile soils and adequate temperature and humidity, in which, due to the extent of damage, farmer leave their fields (Najafi et al 2010).

Tuber viability elimination or prevent tuber production are the ways to successful management of *C. rotundus* (Webster et al 2017). Temperature treatments (e.g., solarization, steam and electromagnetic radiation) have been proposed as alternatives to methyl bromide for pest management (Kokalis-Burelle et al 2016). The tubers of *C. rotundus* died when they exposed to 50 °C for 96 h, whereas exposure for 48 h did not affect tuber viability. Also, the tubers died at 60 °C for one hour (Smith & Fick 1937). In another study, the tubers were died at 90 °C for 30 min, whereas at 50 and 60 °C it was reduced by 10 to 20%, respectively (Rubin & Benjamin 1984). Ransom et al (2003) reported that the plant densities at five locations ranged from 28 to 67 shoots ft⁻², and onion yields were 23 to 64 percent less with yellow nutsedge compared to weed free conditions.

Kumar et al (2012) studied about *C. rotundus* management in a soybean-wheat cropping system. The authors reported that a significant reduction in the plant density and increase in soybean and wheat yields were observed due to solarization followed by the application of glyphosate. Soil solarization, herbicide and tillage independently show variable effects on *C. rotundus* (Grichar & Sestak 2000; Edenfield et al 2005; Bangarwa et al 2008; Das & Yaduraju 2008; Gill et al 2009; Gill & McSorley 2010). Soil solarization covered by polyethylene mulch is a method to increase soil temperature and its effect has proven against many weeds such as *Orobanche crenata*, *O. ramose* and *C. rotundus* (Abouzienna & Haggag 2016). Solarization during summer controls *C. rotundus* due to deadly temperatures near the soil surface (Chase et al 1999; Webster 2003). Onion yield was significantly enhanced by solarization (Abouzienna & Haggag 2016).

Frequent tillage and application of polyethylene film with or without turnip resulted in a lower density of large tubers of *C. rotundus* in bell pepper cultivation (Bangarwa et al 2008). In order to decrease the multiplication of *C. rotundus* tubers, shallow tillage at frequent intervals is needed (Bangarwa et al 2008). *C. rotundus* was effectively managed by glyphosate and paraquat (Iqbal et al 2012). The density of *C. rotundus* was reduced due to the glyphosate application in soybean (Reddy & Bryson 2009). The viability of tubers was reduced by 80% and 65% in soybean and cotton, respectively, due to glyphosate application (Edenfield et al 2005).

Although many studies have been carried out on the use of different treatments to control of *C. rotundus*, to the best of our knowledge there is no comprehensive research on the use of combination treatments. Therefore, the objectives of this study were to evaluate the effects of solarization duration and tuber weight on tuber viability and the number of produced tubers of *C. rotundus* and effect of different treatments on the weed control and onion yield.

2. Material and Methods

2.1. Plant material, experimental location and soil properties

Two separate experiments were conducted in south of Kerman Agricultural Research and Education Center, Jiroft, Iran, during the summer 2017. Onion transplanting was carried out using Rio Bravo variety from Nun Hems Company. Also, The *C. rotundus* tubers were collected from 0-30 cm depth of the field soil. The result of the physical and chemical properties of the location soil was present in Table 1. The experimental soil of the location was sandy loam in texture and a pH of 7.4. Some meteorological data for the experimental area were present in Table 2.

Table 1- Physical and chemical characteristics of the experimental soil

<i>Physical properties</i>					
Clay (%)	Silt (%)	Fine sand (%)	Soil texture		
12	18.5	69.5	Sandy loam		
<i>Chemical properties</i>					
pH	ECe (ds m ⁻¹)	Organic matter (%)	N (%)	P (mg kg ⁻¹)	K (mg kg ⁻¹)
7.4	2.23	0.48	0.48	7.5	2.1

Table 2- Some meteorological data for the experimental area

Month	Temperature (°C)			Total monthly precipitation (mm)
	Average	Maximum	Minimum	
March	20.9	30.8	11.1	64.1
April	27.1	39.8	14.4	2.9
May	33.8	46.4	21.3	6.1
June	37.5	48.2	26.8	0.0
July	37.4	46.2	28.6	0.8
August	35.6	44.4	26.8	2.0
September	32.4	43.2	21.7	0.0
October	28.6	39.4	17.8	0.0
November	21.6	33.6	9.6	6.0
December	21.0	37.9	4.2	0.0
January	13.7	18.1	9.3	10.0
February	19.5	23.8	15.1	22.0

2.2. Solarization experiment

The solarization experiment was conducted to investigate the effects of solarization duration and tuber weight on tuber viability and the number of produced tubers of *C. rotundus*. A factorial experiment based on randomized complete block design was carried out with two factors including three levels of tuber weight including 0.2 g (small), 0.5 g (medium) and 1 g (large) and five levels of solarization duration [0 (control), 5, 10, 15, and 20 days] with three replications. The *C. rotundus* tubers were placed under solarization on the plowing surface for different treatments. The maximum temperature of the location during the August and September months was more than 40 °C (Table 2). In order to assay the tuber viability and the number of produced tubers, the fifteen tubers from each treatment were randomly selected and cultured in 15×30 cm pots in the 2.5 cm depth. The pots were irrigated by drip irrigation.

Tuber viability was calculated by the following formula:

$$\text{Tuber viability} = \frac{\text{The number of sprouted tubers}}{\text{Total tubers sown}} \times 100$$

At the end of the experiment, the soil from pots was washed under tap water onto a metal net (3×3 mm) and the number of produced tubers were counted.

2.3. Weed management experiment

The weed management experiment was conducted as a randomized complete block design with eight treatments and three replications in a field with high contamination of *C. rotundus*. The treatments were included:

T1: Deep disking twice with 20 days interval followed by application of Glyphosate 410 g a.i. L⁻¹ at 3360 g a.i. ha⁻¹, T2: Deep plowing followed by disk two weeks after plowing, T3: Hand plucking, T4: Soil solarization with transparent polyethylene plastic in the second half of August, T5: T4 treatment followed by glyphosate two weeks after removing the plastic before onion transplanting, T6: Un-weeded control, T7: Three times plowing at three weeks intervals, T8: Deep disking twice with 20 days interval followed by application of glyphosate twice after each disk.

Each plot consisted of four furrows with 6 m long and 50 cm apart, each furrow contained four rows. In order to study the weed density, after the treatments, a fixed quadrat was used before weed emergence. Also, during the experiment all other weeds were controlled. In the end of growing season, the following characters were measured, the weed density, shoot and tuber dry weights (g), weed control (%), number of tubers, and onion yield. The tuber populations from each plot were counted in an area of 25 cm² by 20 cm deep volumes of the soil. The soil was sifted by a 5 mm sieve to record the total number of tubers. In order to measure dry weights of shoot and tuber, they were placed in the oven for 72 h at 75 °C. As suggested by Üstüner & Güncan (2002), in the present study the high weed density was used (The average plant more than 10 in per square meter). *C. rotundus* control index (CCI) (Das 2008) which estimate treatment efficiency based on the reduction in *C. rotundus* dry weight, was calculated using the following formula.

$$CCI (\%) = [(CDW_c - CDW_t) \times 100 / CDW_c]$$

Where; CDW_c and CDW_t are the weed dry weight (g m^{-2}) of *C. rotundus* in control and treated plots, respectively.

2.4. Statistical analysis

Two experiments were performed. The experiments were carried out based on the factorial experiment in a randomized complete block (RCBD) and RCBD, respectively. Analysis of variance was done using SAS software (SAS Institute, Inc., Cary, NC). Then, post-hoc Fisher LSD (least significant difference) test at a 5% probability level was carried out to compare the difference among the treatments.

3. Results and Discussion

3.1. The solarization experiment

The results of the analysis of variance indicated that the interaction effects of solarization duration and tuber weight was significant for both measured characters (data not shown). There was a significant difference between control treatment (non-solarization) and different solarization durations. In all solarization durations, tuber viability was eliminated. The maximum percentage of tuber viability was found in the interaction of non-solarization with large and medium tuber weight (Table 3).

Table 3- Interaction of solarization duration and tuber weight on tuber viability and the number of produced tuber of *C. rotundus*

Character	Control			5 days			10 days			15 days			20 days		
	Tuber weight (g)														
	0.2	0.5	1	0.2	0.5	1	0.2	0.5	1	0.2	0.5	1	0.2	0.5	1
Tuber viability	85b	100a	100a	0c	0c	0c	0c	0c	0c	0c	0c	0c	0c	0c	0c
No. of produced tuber	5b	5b	7a	0c	0c	0c	0c	0c	0c	0c	0c	0c	0c	0c	0c

The same letter within each column indicates no significant difference among treatments ($P < 0.05$)

The solarization of tubers at a high temperature for a short period of solarization duration leads to effective control and reduction in the tuber viability of *C. rotundus*. Therefore, any farming activities that can place more tubers on the soil surface and exposed them to solarization in warm and dry seasons, such as plowing and repeated discs even at a short period, can dramatically and effectively reduce the damage of this weed. As the area temperatures in August and September months reaches above 40 °C, therefore these temperatures are sufficient to eliminate the weed tubers. Same as our results, previous studies showed that the high temperature prevented the tuber viability of *C. rotundus* (Webster 2003). The high temperature affects the hydrogen and disulfide bonds in proteins, lipids and the membrane structure (Ahmad et al 1996). The lateral mechanisms of thermal death or reduction in the number of tubers are due to the inactivation of respiratory enzymes, damage to the synthesis of proteins, as well as damage to nucleic acids (Katan 2015). The previous study revealed that *C. dactylon* was eliminated when exposed to a high temperature (40 °C for 30 min), whereas the tuber viability of *C. rotundus* at high temperature (above 60 °C) was decreased, indicating the survival potential of this weed (Rubin & Benjamin 1984). All the interaction treatments between solarization durations with tuber weights (except the interaction between the control with the three tuber weights), prevented the tuber production. Successful management of purple and *C. esculentus* is related to the elimination of tuber viability and tuber production (Roozkhosh et al 2017). Solarization, steam and electromagnetic radiation treatments that produced high temperature can be used instead of methyl bromide for different pests control (Webster 2003; Stapleton et al 2000; Kumar et al 2012; Díaz-Hernández et al 2017).

3.2. The weed management experiment

The results of ANOVA indicated that the effect of management methods on the measured characters including weed density, shoot and tuber dry weights, and control percentage and onion yield was significant at 1% level (Table 4). The low values of the coefficient of variation (CV) showed that the traits were measured with high accuracy. The results of means comparison showed that hand plucking (T3) was the best treatment for *C. rotundus* management. Also, the highest onion yield was obtained in this treatment (96.53 ton ha^{-1} ; Table 5). Although T3 was the best treatment, it had some

problems such as high cost and time consuming (personal observation). Hand plucking method is not possible on large plots as a method. Among the other treatment, T8 was the best treatment for weed control. It seems that application of this treatment in successful weed control was due to two main reason; first, the double disc during the warm and dry months causes more tubers to be exposed to hot sunshine, and secondly, Glyphosate has eliminated the tubers. The tubers of *C. rotundus* are weakened by soil solarization and will be susceptible to Glyphosate herbicide (Peerzada 2017; Johnson et al 2007). Many researchers have suggested that among the management strategies, the solarization and many summer plowing can be more effective to reduce vegetative growth and tuber production of *C. rotundus* (Wang et al 2009). After T3, it had the lowest plant density ($8n\ m^{-2}$) and shoot dry weight (7.9 g), and the characters were reduced by 86 and 88% compared to control treatment, respectively. After un-weeded control treatment (T6), T4 had the lowest effect on weed control. No weed plant was observed during the application of T4 treatment, but after removing the plastic and planting the onions, this treatment showed the highest weed density and dry weight than other treatments, except for T6 treatment. It seems that solarization can stimulate tubers germination. Egley (1983) reported that 3 to 4 weeks of solarization not only did not decrease *C. rotundus* emergence but also in some cases it was increased. It also seems that solarization cannot affect the tubers which located at downward depths. Light and sandy texture of the soil allowed the tubers to penetrate and distribute at the downward depths. Therefore, a low percentage of the tubers were affected in this soil by solarization. The tubers that located at depths of more than 10 cm, not only escaped from solarization due to the absence of lethal temperature but also they were stimulated to germinate (Rubin & Benjamin 1984). When the depth of tubers increased from 10 to 15 cm, *C. rotundus* control was reduced by 32%. After hand plucking treatment (T3; 0 tubers) the T8 treatment had the minimum number of produced tubers (13 tubers $0.05\ m^{-3}$ soil), whereas the control treatment (T6) had the highest number of tubers (98 tubers $0.05\ m^{-3}$ soil). The previous study showed that transparent polyethylene mulch reduced the *C. rotundus* density by 79% compared with control (Webster et al 2008). Solarization effectively controlled the *C. esculentus* and significantly reduced the number of tuber in the soil (Johnson et al 2007). The production of the new *C. esculentus* tubers was stopped after exposure at 50, 55 and 60 °C for 1, 4 and 16 h, respectively (Webster 2003). After hand plucking (0 g), the T8 treatment had the lowest tuber dry weight (6.85 g), and control treatment had the highest value for this trait (52.55 g). The results showed that the highest control percentage was obtained from hand plucking treatment (100%) followed by T8, T7 and T1 treatments (88.6, 82.03 and 77.03%, respectively). The lowest control percentage was achieved from un-weeded control (T6) and soil solarization using transparent polyethylene treatment (T4) by 0 and 43.3%, respectively.

Table 4- ANOVA for the effect of different weed managements on the weed control and onion yield

Source of variation	df	Mean square of traits (MS)					
		Weed density	Weed shoot dry weight	Weed control %	Number of produced tuber	Weed tuber dry weight	Onion yield
Replication	2	6.5 ^{ns}	2.5 [*]	14.51 [*]	18.3 [*]	9.29 [*]	9.6 ^{ns}
Treatment	7	937 ^{**}	1449 ^{**}	799 ^{**}	2780 ^{**}	779.26 ^{**}	2579 ^{**}
Error	14	2.3	4.21	3.70	6.05	3.97	17.69
CV%		5.6	8.44	2.95	5.3	8.1	10.47

ns, no significant; ** and *, are significant at 1 and 5% level, respectively

Table 5- Means comparison of the *C. rotundus* measured characters

Treatment	Density (plant m^{-2})	Shoot dry weight (g m^{-2})	Control (%)	Tuber dry weight (g $0.05\ m^{-3}$)	Number. of produced tuber ($0.05\ m^3$ soil)
T1	25.6 ^d	16 ^d	77.03 ^d	22.97 ^d	45 ^d
T2	31.3 ^c	23.8 ^c	65.76 ^e	27.71 ^c	53 ^c
T3	0 ^f	0 ^f	100 ^a	0 ^f	0 ^f
T4	37.6 ^b	39.6 ^b	43.33 ^f	29.15 ^c	54 ^c
T5	31.3 ^c	24.7 ^c	64.43 ^e	33.65 ^b	67 ^b
T6	57.6 ^a	69.9 ^a	0 ^g	52.55 ^a	98 ^a
T7	25 ^d	12.5 ^d	82.03 ^c	23.34 ^d	42 ^d
T8	8 ^e	7.9 ^e	88.6 ^b	6.85 ^e	13 ^e
LSD (P<0.05)	2.65	3.59	3.37	3.49	4.30

Within each column, the same letter indicates no significant differences among treatments (P<0.01)

Application of different management methods of *C. rotundus* had many fluctuations in onion yield. The highest onion yield was obtained in T3 treatment by 96.53 ton ha⁻¹, followed by T8, T7 and T1 treatments by 70.67, 40.67 and 34.13 ton ha⁻¹, respectively (Figure 1). Also, after un-weeded control treatment, the lowest onion yield was obtained from T5 treatment (14.47 ton ha⁻¹). T4 treatment had more weed density as well as onion yield than T5 treatment, and this reduced of onion yield in T5 than T4 was due to the effects of glyphosate phytotoxicity on the onion plant in T5.

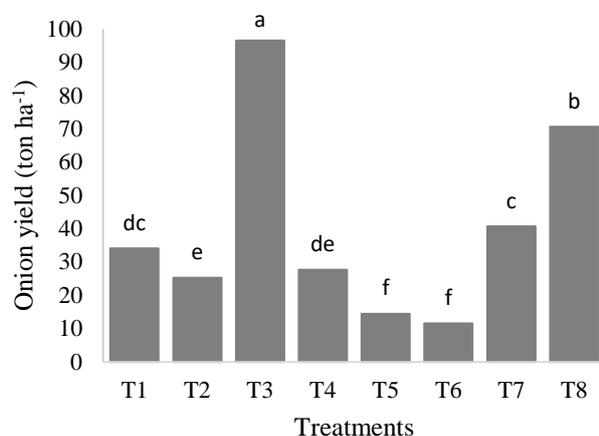


Figure 1- Mean comparison of onion yield under different *C. rotundus* managements

4. Conclusions

The tubers are one of the main ways of *C. rotundus* reproduction. The results of the solarization experiment showed that the solarization of tubers at a high temperature for a short period of time leads to effective control and reduction in the tuber viability of the weed. Therefore, any farming activities that can place more tubers on the soil surface and exposed them to solarization in warm and dry seasons, such as plowing and repeated discs, can dramatically and effectively reduce the damage of this weed. Also, the result of the weed management experiment revealed that the lowest weed density and the highest onion yield were achieved in T3 and T8 treatments. Whereas hand plucking (T3) was very laborious and costly, therefore deep disking twice with 20 days interval followed by application of glyphosate twice after each disk (T8) was found to be the most effective treatment in controlling weeds.

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