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Biological Behavior of *Cyperus rotundus* in Relation to Agro-Ecological Conditions and Imposed Human Factors

Abdessatar Omezine[1*] • Fethia Harzallah-Skhiri[2]

[1] Department of Plant Protection and Biological Sciences, Weed Science Laboratory, Institute Superior Agronomic Chott-Mariem (4042) Sousse, Tunisia
[2] Agrobiodiversity Unit, Higher Institute of Agronomy Chott-Mariem (4042) Sousse, Tunisia, Higher Institute of Biotechnology of Monastir, Tunisia

Corresponding author: * abdessatar.omezine@yahoo.fr

ABSTRACT

Field and laboratory experiments were conducted to study the biological behavior of *C. rotundus* over a two-year period (2006-2007). Spatial distribution, viability and tuber formation were investigated. The effect of propagule size, storage conditions, soil moisture and multiple tubers in rhizome chains on tuber sprouting of *C. rotundus* were determined. *C. rotundus* forms a large number of tubers per plant, 46% of which are able to sprout. However, 54% undergo dormancy. Distribution of tubers in the soil profile is most abundant in the 0-12 cm layer, accounting for 78.6% of all tubers but the depth can attain 40 cm and is expected to be deeper. In *C. rotundus*, the apical bud inhibits sprouting in other buds on the same tuber, and the top tuber exerts a similar dominance over the lower tubers in the system. The viability of tubers decreases in an inverse linear manner over an increasing range of burial depth. *C. rotundus* tubers are very sensible to desiccation. Moisture levels in the soil must increase to a critical level before sprouting occurs, but excess soil moisture deters sprouting. Tuber emergence and emergence time depend upon tuber size and burial depth. Systems to manipulate sprouting may provide new strategies for *C. rotundus* management.

Keywords: apical dominance, emergence, life cycle, regenerative capacity, tuber, viability

INTRODUCTION

Worldwide, the family Cyperaceae includes approximately 3000 species of which about 220 are identified as weeds and of which 42% are in the genus *Cyperus* (Bendixen and Nandihalli 1987). *C. rotundus* can be found on all continents, especially in tropical and subtropical regions, except for Antarctica (Bendixen and Nandihalli 1987). It infests 52 crops in 92 countries (Holm *et al*. 1991) causing tremendous losses and therefore it is considered one of the world's worst weeds (Holm *et al*. 1991).

However in Tunisia, The family Cyperaceae has 37 species of which *C. rotundus* was identified as a weed (Labbé 1952). The intensification of local agriculture increased their infestation and therefore it became the most pernicious weed in Tunisian irrigated horticultural crops (Omezine 1990). In Tunisia *C. rotundus* infests cultivated fields, waste areas, roadsides, pastures, and natural areas. It is considered a pernicious weed for the irrigated land because of its insidious, rapid growth in flowerbeds and among vegetable crops.

C. rotundus produces abundant seeds and tubers. It apparently produces relatively few viable seeds. Its reproduction through seeds has not been observed in Tunisia (Omezine 1990). However, asexual reproduction of *C. rotundus* is the most important means of propagation, due to its profuse production of rhizomes, basal bulbs and tubers. The vertical distribution of tubers in the soil profile varies with the level of infestation and location. Horowitz (1972) estimated that 60–70% of tubers were in the 0–20 cm layer. However, Siriwardana and Nishimoto (1987) found that 95% of the tubers were in the upper 30 cm of soil. Lower depths of soil contained larger tubers with higher percent dry matter than shallow depths (Siriwardana and Nishimoto 1987). These tubers undergo periods of dormancy, especially when separated from the mother plant (Stoller and Sweet 1987). The varying degrees of tuber dormancy cause irregular emergence of *C. rotundus* and greatly contribute towards its persistence as a weed. The sprouting of tubers is strongly regulated by apical dominance (Cline 1991), agro-ecological conditions, and depth (Miles 1991; Miles *et al*. 1996; Holt and Orcutt 1996). Sprouting rate and percentage were significantly and consistently higher for the tubers originating from the upper soil layer (Travlos *et al*. 2009).

The survival strategies of *C. rotundus* have been studied in relation to desiccation rate, dry matter content and burial depths. Critical moisture level of the tubers is 43% and minimum soil moisture is about 0.4%, for its survival (Nishimoto 2000). However, burial depth at the upper layer at 20 cm depth had no significant effect on survival or dormancy (Neeser *et al*. 1997).

A greater understanding of the biological behavior in horticultural production systems will be an initial step in devising appropriate management strategies; an appreciation of its ability to spread and reproduce can help predict the potential of its spread into new areas and be useful in developing effective control measures. Because tubers play an important role in the propagation of this weed, best control could be achieved by reducing density of viable tubers (Akin and Shaw 2001). Effective *C. rotundus* management programs must address tuber production and viability. The purpose of this research was to examine the importance of the underground system, dormancy and sprouting regulation, and tuber survival of *C. rotundus* in field and laboratory conditions.

MATERIALS AND METHODS

Plant material and experimental conditions

C. rotundus tubers were collected from one field orchard from a solitary stand to avoid biotype effects. *C. rotundus* tuber samples were collected on March 2006 and 2007 for use in vegetative studies. A part of the sample tubers were stored in a refrigerator at

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4°C in plastic bags until assigned experimental treatments. The other part of sample tubers was used directly the same day of their excavation. The experiments were watered every two days with 200 ml of de-ionized water as needed to avoid water stress.

Effects of propagule size in relation of depth on sprouting and emergence

To determine the smallest viable size, four masses of sample tubers were chosen: 0.2, 0.5, 0.8, 1.0 g. Planting depths were 0, 2, 5, 10, 20, 30 and 40 cm. 5 tubers were used for each size and each planting depth. Tubers were planted in 16 cm diameter tubes and 50 cm deep filled with 50% of peat moss and 50% of vermiculate by volume (denominated potting media) on 20 March 2006. The tubes were placed outdoors in ambient conditions in the ISA laboratory field. After one month, the number of sprouted tubers was counted.

Effect of rhizome chain on tuber sprouting

C. rotundus rhizome chains were collected from the same site mentioned above to determine the effect of length of chain on tuber sprouting. Four rhizome chain lengths were collected (one, two, three and four tuber-rhizomes). 10 rhizome chains of each length were collected on the same day when they were planted in 16-cm containers filled the potting media on 20 March 2006. All propagules were planted in the laboratory field. After 15 days, the number of sprouted tubers was counted and removed. After removal of sprouted tubers, the rhizome chains were replanted; after 15 days of rhizome chain re-plantation, the number of sprouted tubers was counted again and removed. This phenomenon was repeated until no more tubers sprouted.

Effects of soil type and soil moisture (irrigation regime) on sprouting

This experiment was a two factorial design with 10 replicates. The factors were soil type and soil moisture. Each 5 tubers were planted ~2 cm deep in clay, sandy silt loam, sandy loam, sandy soil or peat moss media in 15-cm diameter containers on 15th March 2006. One third of the containers were watered daily with 200 ml of de-ionized water; the second third of the containers was watered weekly with the same quantity and quality of water as the first third; the last third was not watered at all. The containers were placed outdoors at ambient conditions in the ISA laboratory field. After 15 days, the number of sprouted tubers was counted.

Effects of tuber storage on sprouting

Storage treatments were assigned on March 2006 with 10 replicates to test the effects of temperature and storage duration on tuber sprouting. The storage treatments simulated environments which *C. rotundus* tubers might encounter in crop habitats. Sample tubers were collected from the same place as mentioned above. Half of the tubers were stored in a refrigerator at 4°C (winter time), while the other half were placed at ambient temperature (25°C). Every two days, 10 tubers of each storage condition were planted in 15-cm diameter pots filled with potting media. After 15 days of tuber plantation, the number of tubers that sprouted was counted.

Spatial distribution, viability and production of tubers

To obtain rough information about spatial distribution of tubers in the soil horizons, small soil monoliths were taken on May 2007 according to Görbing (1948), each of which was 400 cm^2 in area. Layers of soil were taken at the following depths: 0-2, 2-12, 12-22, 22-2, and 32-42 cm (Köpke 1979). Soil was washed through a screen and firm and soft tubers were counted. Soft tubers were those that could be crushed in the hand with moderate pressure, and were presumed dead. Before extracting the monoliths, the vegetative above-ground part was cut and weighed to determine biomass production.

Observation of underground system growth pattern and development of *C. rotundus*

An experiment was designed on March 2007 to make phenological observation of the underground system, growth pattern and development of *C. rotundus*. This experiment utilized glass-faced containers, generally inclined at angles of about 25° from the vertical (glass side down). The glass-facing containers are made of wood with two sides' walls containing a removable glass plate. A thick paper is used to cover the glass and protect the underground system from light. The size of the glass observation containers is at the bottom 10 cm large and 50 cm long, at the upper surface 15 cm large, and the height of the containers is 40 cm. The growth and the development of *C. rotundus* were followed from the plantation until the death of the above-ground part. The number of tuber produced was estimated at the end of the experiment.

Statistical analysis

Ten replicates per treatment were planted within a completely randomized design. The data were subjected to analysis of variance appropriate to each experiment (ANOVA) in order to test for single factors and the *F*-test was calculated (Little and Hill 1978) and finally standard errors were used to compare treatment means.

RESULTS

Spatial distribution, viability and production of tubers

Results of spatial distribution, tuber viability and tuber production are presented in **Table 1** and **Fig. 1**. The majority of *C. rotundus* tubers are relatively shallow: 85% of the tubers are within the top 10 cm of the soil profile and 95% are found within the top 20 cm of the soil profile. Few tubers penetrate to a depth of 40 cm. From tuber stock, only 15% of the tubers were soft (decayed) and presumed dead while 85% were either firm tubers or basal bulbs (Basal bulbs are primary site for prolific vegetative growth because they contain the meristem for leaves, rhizomes, roots and flower stalks). The basal bulbs constituted 10.9% of the tubers and nutlets found in the soil profile. The total number of tubers and basal bulbs found in the soil was 279 tubers in 16000 cm^3 of soil. *C. rotundus* produced the equivalent of 55 million tubers and basal bulbs/ha. Moreover, this study revealed that 10% of tubers had less than 0.02 g, 28% had a weight between 0.02 and 0.40 g, 49% between 0.40 and 0.90 g, 8% larger than 1 g and 5% decayed tubers. Roots

Table 1 Number and percentage of tubers and basal tubers, viability in percentage of these structures excavated from different soil horizons. Each soil horizon has 20 cm × 20 cm × 10 cm except for the upper one 20 cm × 20 cm × 2 cm.

Soil depth	Number of tuber	Tubers*			Basal tubers*		
(cm)	(means of 5 repetitions)	Number	%	Viability	Number	%	Viability
0-2	22.2	9.8	44.1	38.4	12.4	55.9	0.0
2-12	59.6	45.8	76.8	48.9	13.8	23.2	0.0
12-22	23.2	20.4	87.9	56.9	2.8	12.1	0.0
22-32	9.2	8.0	86.9	70.8	1.2	13.1	0.0
32-42	3.4	2.8	82.3	15.0	0.6	17.7	0.0
Total	134.6	86.8	63.0	46.0	30.8	37.0	0.0

* average of 5 repetitions.

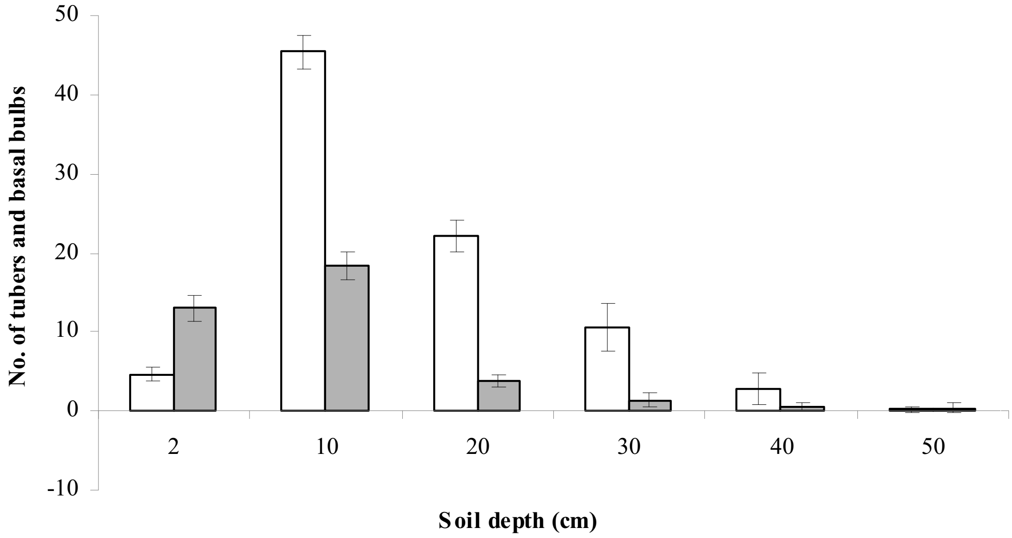

Fig. 1 Number of tubers (white) and basal bulbs (grey) in different soil profiles. Values represent mean ± Standard Error (SE).

often grow to greater soil depths than tubers or rhizomes and may extend more than 40 cm deep. They constitute only a small portion of the total biomass. However, rhizomes, tubers and basal bulbs dominate the subterranean part of the plant.

The viability test of these tubers indicated that almost 54% of tubers excavated from different soil horizons were unable to sprout (dormant) and 46% of those tubers were able to sprout after one week of planting. Therefore, the germination of basal bulbs was nil. Greater sprouting rate was observed among large tubers compared to smaller ones. The larger tubers were able to sprout rapidly and form many shoots and tubers.

Observation of underground system growth pattern and development of *C. rotundus*

From a single tuber planted in the view box in the greenhouse (**Figs. 2, 3**), only one or two rhizomes were released vertically (orthotropic rhizomes). Once the rhizome reached the soil surface, it formed a special green shoot, called a vegetative basal tuber. The basal tuber swelled at the base and unleashed three types of growth: (1) an upright shoot with the leaves; (2) a shallow underground runner which moves horizontally (diagiotropic rhizomes) a few centimeters away from the mother basal tuber; this new runner re-established another basal tuber with leaves and thus another plant; (3) a deep underground runner which moves downward (plagiotropic rhizomes) to form a tuber chain. Secondly, the initial mother tuber can also release rhizomes downward forming individual tubers or tuber chains. New tuber formation began 4 to 6 weeks after new shoot emergence. This phenomenon occurred repeatedly in the growing season by the end of which all these new plants had made enough food to make new nutlets (daughter tubers). Thus, the plant top turned yellow and died back in mid fall until early winter when the temperature decreased, leaving an extensive underground tuber system to over-winter in the soil; these tubers will survive and sprout the following spring when the soil temperatures increase and the cycle restarts the following year. The new tubers have 5-7 growing points (buds). One bud on one nutlet could give rise to 10-15 plants per season, So that the number of tuber produced per tuber planted was 300 tubers. The result is an increased stand of *C. rotundus* plants. Such a conservative tactic results in a profitable stand of *C. rotundus*. This result explains the persistence of *C. rotundus* in the soil. *C. rotundus* bloomed 6 to 8 weeks after shoot emergence (based on simple observations).

Fig. 3 Underground tuber system of *Cyperus rotundus*.

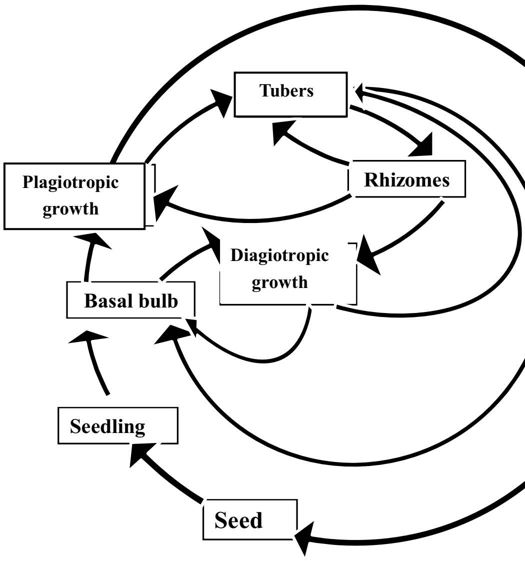

Fig. 2 Growth pattern of *Cyperus rotundus*.

Effect of size and burial depth of tubers on time of shoot emergence and tuber production

Tubers buried at 2 cm emerged in one week; the time required for tubers planted at 50 cm is 90 days after planting. Tubers could not emerge from a burial depth over 50 cm but sprouted and formed basal bulbs and finally they died halfway before reaching the soil surface. Also planting depth influenced the rate of emergence: 99.8% of *C. rotundus* tubers had emerged from tubers planted at a 2-cm depth

Table 2 *Cyperus rotundus** shoot emergence and tuber production per pot influenced by depth of plantation. (Tubers have 1.0 g weight).

Depth of burial (cm)	Time of emergence (days after plantation	Emergence	Tubers production (number of tubers/pot, 16 cm diameter)
2	7 a	99.8 a	115 a
5	15 b	97.3 a	180 b
10	30 c	96.2 a	340 c
20	38 d	35.1 c	350 c
30	50 e	25.3 d	345 c
40	72 f	15.4 e	102 d
50	90 g	5.1 f	62 e
60	* i	* j	3 f
70	* i	* j	2 f

**Cyperus rotundus* tubers were buried at the various depths on March 30, 2006 and *Cyperus rotundus* shoots and tubers were harvested on July1, 2006. Means in a column followed by the same letter are not significantly different at p=0.05.

Table 3 Effect of *Cyperus rotundus* tuber size planted at 2 cm depth on emergence and sprouting expressed in percentage after 15 days of plantation.

Tuber weight	Emergence	Sprouting
0.02	5.3 a	48.3 a
0.5	90.5 b	85.5 b
1.0	96.4 b	92.7 b
1.5	99.5 b	98.9 b

Means in column followed by the same letter were not significantly different at p=0.05

Table 4 Sprouting of tubers, shoot number and number of new tubers per tuber planted in relation with irrigation regime.

Soil type	Sprouting of tuber	Shoot number	Number of new tubers
Without irrigation	None	0	0
Irrigation every day	All	3	5
Irrigation every week	All	1	2

whereas only 5.1% were able to emerge from tubers planted at a 50-cm depth (**Table 2**). The number of tubers was lower for pots where the planting depth was ≥40 cm, decreasing significantly as depth increased from 2 to 40 cm. This study demonstrated that depth of burial delayed *C. rotundus* shoot emergence. Fewer shoots emerged and at depths below 50 cm were also smaller. 350 tubers are produced in the upper 20 cm of soil.

The size of *C. rotundus* tubers did not affect sprouting but did affect emergence (**Table 2**). Larger tubers are more successful in producing shoots that emerge. The greater the size of the tuber, the deeper tuber may emerge (**Table 3**). Sprouting did not depend upon the size of the tuber, 5.3% of 0.02 g tubers were able to emerge but 48.3% of these tubers were able to sprout (**Table 4**). However, almost more than 98% of 1.5 g tubers were able to emerge and sprout. Thus emergence from greater depths needed more carbohydrate content. Basal bulbs were unable to sprout and to emerge. These results indicated that an inverse relationship exists between depth of burial and emergence and a direct relationship between burial depth and emergence time for *C. rotundus*.

Effect of soil moisture and type of soil

Irrigation regime had a significant effect on *C. rotundus* shoot number and tuber production (**Table 5**). Under high frequency, i.e. one irrigation/day, *C. rotundus* produced 3 shoots/tuber. This was significantly greater than the irrigation every week, in which it produced 1 shoot/planted tuber. Without irrigation, *C. rotundus* did not produce either shoots or tubers. *C. rotundus* tuber production was higher with daily irrigation than other irrigation parameters. An average of 5 tubers was produced from a single plant with daily irrigation; 2 from the weekly irrigation treatment. Moisture levels in the soil must increase to a critical level before sprouting occurs, but excess soil moisture deters sprouting (Nishomoto 2001).

Moreover, soil type had an influence on *C. rotundus* tuber production and emergence time (**Table 6**). Tubers planted in sandy soil emerged sooner than those in sandy loam soil, but tubers in sandy silt loam soil produced more plants. Tubers planted in peat moss produced the most tubers and emerged in 8 days. *C. rotundus* tubers did not emerge from clay soil for a month. *C. rotundus* tubers started to grow from the other 4 less-compacted soils after 8 days. The emergence was 10, 13, 15 days respectively, for sandy silt loam, sandy loam, and sandy soil. Both emergence and percentage of sprouting of *C. rotundus* were nil by clay soil (**Table 5**).

Effect of apical bud and tip tuber in a rhizome chain on other buds and tubers

In *C. rotundus* the apical bud of a single tuber sprouted first (**Table 7**). In a rhizome chain of tubers, the tuber at the morphological apex (tip) prevented sprouting of the other tubers in the chain (**Table 8**). This dominance is not a strong as that exerted by the apical bud within a tuber itself. The separation of a tuber from a chain of tubers removes it from the apical dominance of the apical tuber in the chain. Therefore, the top tuber in a chain or the top bud in an indi-

Table 5 Tuber production on the base of 100 tubers planted in relation with the soil type during one season and emergence time (from March to July 2007).

Soil type	Emergence time (days)	Quantity in number
Clay soil	0	0
Sandy soil	10	105 a
Sandy loam	13	123 b
Sandy silt loam	15	151 c
Peat moss	8	188 d

Table 6 Sprouting and emergence of *Cyperus rotundus* as affected per tuber size.

Tuber fresh weight (g)	Tuber sprouting (%)	Emergence at burial depth of 40 cm
1.50	98.6 a	95.2 a
1.00	95.2 a	92.4 a
0.50	96.4 a	60.8 b
0.05	91.3 a	50.2 c
Basal bulbs	0.0 b	0.0 d

Means in a column followed by the same letter are not significantly different at p=0.05.

Table 7 Effect of tuber apex on bud sprouting (10 repetitions of 1 tuber).

Presence or absence of apex	Number of shoots emerged
Tubers avec apex	1 shoot/tuber (emerged from apical bud)
Tubers sans apex	3shoots/tuber (emerged from lateral buds)

Table 8 Effect of chain tubers on tuber sprouting (10 repetitions of 1 chain length).

Chain length (in tubers)	Tubers sprouted in the first 15 days	Tubers sprouted after first removal sprouted tubers	Tubers sprouted after second removal sprouted tubers	Tubers sprouted after third removal sprouted tubers
1 chain tuber	10 among 10			
2 chain tubers	10 among 20	10 among 10		
3 chain tubers	10 among 30	10 among 20	10 among 10	
4 chain tubers	10 among 40	10 among 30	10 among 20	10 among 10

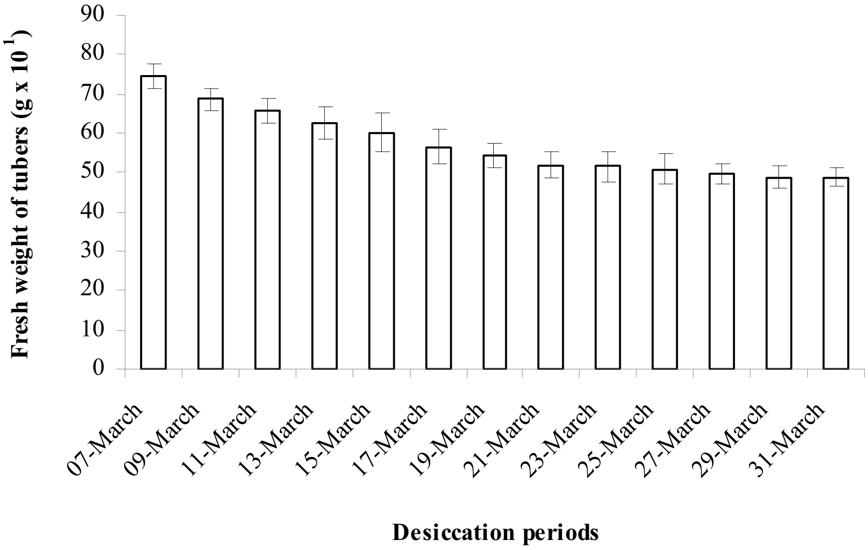

Fig. 4 Evolution of fresh weight (in decigram) in relation with the desiccation periods under ambient temperature (25 ± 2°C). Values represent mean ± Standard Error (SE).

vidual tuber exerted a correlative inhibition over the other tubers or other tuber buds in the system.

Effect of desiccation of tubers

Exposing during 15 days *C. rotundus* tubers to ambient air at 25 ± 2°C killed them. When *C. rotundus* tubers were exposed to ambient temperature until their water contents was 15% (normally they contain 85% water), they did not survive (**Fig. 4**). In this study, it took 15 days under such a temperature condition to achieve 40% loss in fresh weight to kill tubers. Thus water loss was very slow probably due to the thick and impermeable cuticle.

DISCUSSION

Because of its rapid propagation and accelerated growth, *C. rotundus* is capable of producing 40 tons/ha of fresh matter (aerial and subterranean parts), which limits the availability of water to cultivated crops (Horowitz 1972). As for competition for nutrients *C. rorundus* can remove great quantities of nutritive elements from the soil. In the same way, *C. rotundus* competes for light particularly with short crops. Approximate quantities of fertilizer that may be mobilized and stored in *C. rotundus* tubers equal 815 kg of ammonium sulfate, 320 kg of potash, and 200 kg of phosphate per ha (Holm *et al*. 1977). Besides resource competition, evidence suggests that organic substances released from the decay of dead subterranean tissues may be allelopathic and reduce crop yields where *C. rotundus* infestations are severe (Horowitz and Friedman 1971; Omezine 1990). Under experimental conditions, *Hordeum vulgare* yield was reduced by 15-25% (Horowitz and Friedman 1971) and newly planted apricots seedling growth was reduced by 50% by *C. rotundus* residues in the soil (Omezine 1990). Also, the rapid expansion of the subterranean system of *C. rotundus* and the penetrating ability of the rhizomes enable *C. rotundus* to puncture or pierce bulbs of onions, tubers of potatoes and roots of radish or carrot (Leihner *et al*. 1984). This makes these damaged products unacceptable for fresh consumption.

C. rotundus L. is one of the most difficult weeds to control worldwide. In Tunisia, it is an important weed in arable areas with high crop production potential. *C. rotundus* has an extensive underground system of basal bulbs, roots, rhizomes and tubers which permit rapid and vigorous vegetative propagation. The distribution of tubers is most abundant in 0-10 cm layer, which consisted 56% but the depth could attain 40 cm and expected to be deeper. Tuber weight attains 480 mg in average, the heaviest ones, distributed in 30-40 cm depth layer. It is propagated mainly by tubers, which have several buds that can sprout repeatedly which make cultural or manual methods ineffective. The longevity of tubers, the ability of tubers to sprout several times, and the lack of herbicides that can kill dormant tubers have made *C. rotundus* control difficult. Since the major tubers were in the layer of 2-10 cm depth, tubers established well and a single tuber produced more shoots and new tubers planted because a greater percentage of buds sprouted. In contrast, however, productivity declined with deeper planting, and few shoots reached from greater depths. This led to death of the original tubers, without replacement by new tubers.

Buds in a tuber and tubers within a chain exhibit apical dominance. That apical dominance can be broken during cultivation by severing any tuber from the chain. This stimulates dormant tubers to sprout. Due to apical dominance and bud dormancy, tubers stay in the soil for extended periods before sprouting. Control would be facilitated if tuber longevity were short enough so that all buds could sprout at the same time so that the resultant plants can be killed (Stoller and Sweet 1987). *C. rotundus* can be managed by a strategy in which the tuber chains are cut into single tubers by shallow tillage to eliminate apical dominance, and these are then buried by deep plowing to limit their emergence.

The survival strategies of *C. rotundus* have been studied in relation to desiccation rate (Jha and Sen 1985). When *C. rotundus* tubers are dried out until their water contents is 15% (normally they contain 85% water), they will not survive. However, it may take several days or even weeks to achieve this and is therefore highly weather dependent (Stoller and Sweet 1987). Numerous studies indicate that *C. rotundus* tubers are easily killed by desiccation: Smith and Fick (1937) found that *C. rotundus* tubers were killed by exposure to 4 days direct sunlight, 16 days to laboratory or desiccator air, or 32 days of a more humid atmosphere. The critical moisture content of the tubers was 15% compared to 50% for normal *C. rotundus* tubers. Day and Russell (1955) reported that *C. rotundus* tubers did not survive more than 15 days when stored in air-dry sand. Desiccation of tubers by summer fallowing was a traditional method of controlling wandering perennial weeds in Tunisia. The soil was plowed and allowed to dry into clods. These were stirred occasionally with a plow or heavy cultivator to completely desiccate tubers. Plowing dry soil caused *C. rotundus* tubers to die of desiccation. This greatly reduced *C. rotundus* infestation in the subsequent crop. Therefore, Tillage, disrupting the network of *C. rotundus*, induces a positive (lifting of the dormant state, suppression of apical dominance) or negative (drying at the surface, burying the plant) on the development of *C. rotundus*. We must therefore deal with tools that will limit any action that might encourage its propagation and we have to avoid tools which fragment the chain tubers into single tubers or disrupt single tubers. Thus, we have to discard the rotary harrow and the rotavator since these tools can still stimulate and accelerate the resumption of vegetative tubers and accelerate the proliferation. In the same way, uses disk tools can accelerate the proliferation of the weed and lead in the medium term, a significant increase in the total number of tubers per square meter.

Combinations of tillage and chemical methods may be more effective in controlling *C. rotundus* than tillage or herbicides alone. In an integrated control scheme, *C. rotundus* is allowed to row as long as possible after plowing and harrowing have stimulated dormant buds to sprout. Then systematic herbicides, such as glyphosate, that have no residual soil activity are applied. This will provide season long control of *C. rotundus* and if continued over several seasons, may eliminate *C. rotundus* (Warren and Coble 1999).

Mulching with polyethylene sheets alone was also effec-tive in reducing the top growth of *C. rotundus* but was totally ineffective in checking the regrowth (Ahuja and Yaduraju 1995). Because of the relatively hot current Tunisian summer, soil temperature can be achieved 40°C. Rising temperature of sol by solarisation decreases the viability of *C. rotundus* tubers. Solarisation starting in June might be effective, which has the benefit that an early crop can still be grown, or that some tillage operations can be applied to weaken *C. rotundus*. Additionally, solarization seems potentially effective on *C. rotundus* tuber sprouting, as long as it resulted not only to a soil temperature shift, but also to a high diurnal temperature variation (Travlos *et al.* 2009).

Omezine (unpublished data) concluded that explicit management of maize-*C. rotundus* interactions is a new integrated weed management. Maize has the ability to grow vertically and form rapidly a dense canopy which is the most critical factors in competition for light, water and nutrients.

There are reports of success in reducing weed interference in different cropping systems with the aid of biological control agents. Biological control may offer an alternative means to manage *C. rotundus* which is susceptible to crop enemies (Brunt *et al.* 1996; Kadir *et al*. 1999). *C. rotundus* is an alternate host for fungus (Pomella and Barreto 1997). It is also infected by nematodes (Norsworthy *et al*. 2005). However, none of these agents causes sufficient destruction to provide sufficient control of this weedy plant (Holm *et al*. 1977), due to low incidence of these enemies and release time (Visalakshy and Jayanth 1995). Efforts at biological control have explored the usefulness of the biological agents and searches have been made for potentially effective biological agents in the world (Frick and Chandler 1978). In Tunisia, unfortunately no work was done on this subject due to lack of researchers and financing project. However, the Tunisian climate is favorable for developing such interesting project.

These results have greatly expanded our understanding of the biological behavior of *C. rotundus*. Successful management requires the integration of knowledge of the biology and ecology of this species with management strategies which include herbicides and cultural crop production practices. In fact, the combination of these findings probably will reduce the *C. rotundus* infestation.

REFERENCES

Ahuja KN, Yaduraju NT (1995) Chemical control of *Cyperus rotundus* and *Cynodon dactylon* under non-crop situations. *Indian Journal of Weed Science* **27**, 180-182

Akin DS, Shaw DR (2001) Purple nutsedge (*Cyperus rotundus*) and yellow nutsedge (*Cyperus esculentus*) control in glyphosate-tolerant soybean (*Glycine max*). *Weed Technology* **15**, 564-570

Bendixen LE, Nandihalli UB (1987) World-wide distribution of purple and yellow nutsedge (*Cyperus rotundus* and *C. esculentus*). *Weed Technology* **1**, 61-65

Black CC, Chen TM, Brown RH (1969) Biochemical basis for plant competetion. *Weed Science* **17**, 338-344

Borchert R (1991) *Growth Periodicity and Dormancy*, John Wiley & Sons, New York, pp 221-245

Brunt AA, Crabtree K, Dallwitz MJ, Gibbs AJ, Watson L (1996) *Viruses of Plants*, CAB International, Wallingford, UK, 1484 pp

Cline MG (1991) Apical dominance. *Botanical Review* **57**, 318-358

Day BE, Russell RC (1955) The effect of drying on survival of nutgrass tubers. *California Agricultural Experiment Station Bulletin* **751**, 6 pp

Frick KE, Chandler JM (1978) Augmenting the moth (*Bactra verutana*) in field plots for early-season suppression of purple nutsedge (*Cyperus rotundus*) biological control. *Weed Science* **26**, 703-710

Galitz DS (1994) The biology of leafy spurge. Proceedings: Leafy Spurge Strategic Planning Workshop, March 29-30 1994, pp 57-62. Available online: www.npal.ndsu.nodak.edu/pdf files/202gal94.pdf

Glaze NC (1987) Cultural and mechanical manipulation of *Cyperus* spp. *Weed Technology* **1**, 82-83

Groenedael JM, Habekotté B (1988) *Cyperus esculentus* L: Biology, population dynamics and possibilities to control this neophyte. *Z. PflKrankh. PflSchutz, Sonderheft* **XI**, 61-69

Görbing J (1948) Die Grundlagen der Gare im praktischen Ackerbau. Hannover, *Landbuch-Verlag* **2** Bande, o.J., 97 pp

Holm LG, Donald P, Pancho JV, Herberger JP (1977) *The World's Worst Weeds: Distribution and Biology*, The University Press of Hawaii, Honolulu, Hawaii, 609 pp

Holm LG, Plucknet DL, Pancho JV, Herberger JP (1991) *The World's Worst Weeds: Distribution and Biology*, Malabaz. FL. Krieger, p 8

Holt JS, Orcutt DR (1996) Temperature thresholds for bud sprouting in perennial weeds and seed germination in cotton. *Weed Science* **44**, 523-533

Horowitz M (1972) Growth, tuber formation and spread of *Cyperus rotundus* L. from single tubers. *Weed Research* **12**, 348-363

Horowitz M, Friedman T (1971) Biological activity of subterranean residues of *Cynodon dactylon* L., *Sorghum halepense* L. and *Cyperus rotundus* L. *Weed Research* **11**, 88-93

Horvath DP (1999) Role of mature leaves in inhibition of root bud growth in *Euphorbia esula* L. *Weed Science* **47**, 544-550

Jha PK, Sen DN (1985) Adaptation and survival strategies in *Cyperus rotundus*. *Folia Geobotanica* **20**, 281-289

Kadir JB, Charudattan R, Stall WM, Bewick TA (1999) Effect of *Dactylaria higginsii* on interference of *Cyperus rotundus* with *L. esculentum*. *Weed Science* **47**, 682-686

Kawabata O, Nishimoto RK (2003) Temperature and rhizome chain effect on sprouting of purple nutsedge (*Cyperus rotundus*) ecotypes. *Weed Science* **51**, 348-355

Kôpke U (1979) Ein Vergleich von Ferd methoden zur bestimmung des wurzelwachstums bei Landwirschaftlichen Kulturpflanzen. PhD thesis, Gottingen University. In: Böhm W (Ed) *Methods of Studying Root Systems* (Vol 33), Springer-Verlag, Berlin, 188 pp

Labbé A (1952) Plants spontanées de Tunisie à floraison estival. *Bulletin du Service Botanique et Agronomique de Tunisie* **20**, 1-26

Leihner D, Doll JD, Fuentes de Piedrahita Fuentas de P, Campo JH (1984) The biology and control of purple nutsedge (*Cyperus rotundus* L.): study guide. Centro International de Agricultura Tropical, Cali, Colombia, 56 pp

Little TM, Hill FJ (1978) *Agricultural Experimental Design and Analysis*, John Wiley and Sons, New York, 350 pp

McIntyre GI (1971) Apical dominance in the rhizome of *Agropyron repens* in isolated rhizomes. *Canadian Journal of Botany* **49**, 99-109

McIntyre GI (1972) Studies on bud development in the rhizomes of *Agropyron repens*. II.The effect of nitrogen supply. *Canadian Journal of Botany* **50**, 393-401

Miles JE (1991) Modeling the sprouting of purple nutsedge L. tubers in response to soil temperatures under soil solarization. PhD thesis, Univeristy of Hawaii, Honolulu, 229 pp

Miles JE, Nishimoto RK, Kawabata O (1996) Diurnally alternating temperatures stimulate sprouting of purple nutsedge (*Cyperus rotundus*) tubers. *Weed Science* **44**, 122-125

Neeser C, Aguero R, Swanton CJ (1997) Survival and dormancy of purple nutsedge (*Cyperus rotundus*) tubers. *Weed Science* **45**, 784-790

Nishimoto RK (2000) *Abstract of the 3rd International Weed Science Congress*, June 6-11, 2000, Foz Do Iguassu, Brazil, pp 255-256

Nishimoto RK (2001) Purple nutsedge tuber sprouting. *Weed Biology and Management* **1**, 203-208

Nooden LD, Weber JA (1979) *Dormancy and Developmental Arrest*, Academic Press, New York, 316 pp

Norsworthy JH, Schroeder J, Thomas SH, Murray LW (2005) Southern root-knot nematode effect on purple nutsedge (*Cyperus rotundus*) and Chile pepper response to halosulfuron, *Weed technology* **19**, 1004-1011

Omezine A (1990) Biodiversité de la flore adventice en Tunisie. *Colloque National sur les Acquis de la Recherche Agronomique*, 12-14 December, Nabeul, Tunisia, pp 24-33

Omezine A (1995) Effet compétitif du chiendent pied de poule et du souchet rond sur les jeunes plantules d'abricotiers. *Colloque National sur les Acquis* *de la Recherche Agronomique*, 12-14 December, Nabeul, Tunisia, pp 12-19

Pomella AWV, Barreto RW (1997) Leaf scorch of purple nutsedge (*Cyperus rotundus*) caused by *Ascochyta cyperiphthora* sp. nov. *Biological Control* **65**, 459-468

Prather T, Hembree K, LeStrange M (1995) Deep plowing for yellow and purple nutsedge control. University of California Cooperative Extension Report, 10 pp

Santos BM, Morales JP, Bewick (1996) Purple nutsegde (*Cyperus rotundus* L.) interference on radish under different nitrogen levels. *Weed Science Society of American* **36**, 69 (Abstract)

Siriwardana G, Nishimoto RK (1987) Propagules of purple nutsedge (*Cyperus rotundus*) in soil. *Weed Technology* **1**, 217-220

Smith EV, Fick GL (1937) Nutgrass eradication studies - Relation of the life history of nutgrass, *Cyperus rotundus* L., to possible method of control. *Journal of the American Society of Agronomy* **29**, 1007-1013

Stall WM, Dusky JA, Gilreath JP (1996) Estimated effectiveness of recommended herbicides on selected common weeds in Florida vegetables. In: Colvin D, Stall W, Crocker T, McCarty L, Norcini J, Coale F, Hall D, Cromwell R, Tucker D, Langeland K, MacDonald G, Brecke B, Dusky J, Gilreath J, Jones D, Meerow A, Meister C, Mislevy P, Singh M, Whitty E (Eds) *Florida Weed Control Guide*, Gainsville, University of Florida, FL, SP-53, pp 343-346

Stoller EW, Sweet RD (1987) Biology and life cycle of purple and yellow nutsedges (*Cyperus rotundus* and *C. esculentus*). *Weed Technology* **1**, 66-73

Travlos IS, Economou G, Kotoulas VE, Kanata PJ, Kontogeorgos AN, Karamanos AI (2009) Potential effects of diurnally alternating temperatures and solarization on purple nutsedge (*Cyperus rotundus*) tuber sprouting. *Journal of Arid Environments* **73**, 22-25

Visalakshy PNG, Jayanth KP (1995) Suppression of *bactra venosana*, a potential natural enemy of *Cyperus rotundus*, by *Trichogrammatoidea bactrae* in Bangalore, India. *Phytoparasitica* **23**, 355-356

Warren Jr. LS, Coble HD (1999) Managing purple nutsedge (*Cyperus rotundus*) populations utilizing herbicide strategies and crop rotation sequences. *Weed Technology* **13**, 494-503