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Ecological study of the invasive weed *Lepidium virginicum* L. in the fields of the Nile Delta coast

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ABSTRACT

Ecological and floristic studies on *Lepidium virgincum* L. in Egypt revealed the occurrence of a new alien plant species, in Ismailia district 2006 by El-Gazzar and Hammodua. In the present study, a newly discovered distribution of *L. virginicum* occupies mesic orchards, field edges and arable field habitats in New Damietta coastal area is evaluated. Associated species recorded and soil characteristics of the newly invaded habitats are analyzed. We present here an exhaustive analysis of morphological, phenological characteristics and growth characteristics *L. virginicum* in the different habitats. We found that *L. virginicum* populations prefer fertile sandy habitats rich in nitrogen and phosphorus. Different growth forms (rosette and erect) and four different leaf morphs (heteries, rhombiodea, tenuis and simplex) dominate during life cycle. Although *L. virginicum* currently occurs in limited distribution as an alien species in Egypt, its existence in other regions of Egypt is highly probable.

The obtained results will be useful for the management and optimizing use of this new invasive, alien weed in the orchards and in the canal bank habitats in the coastal area of Nile Delta.

Key words: Alien species, ecology, identification, invasiveness, *Lepidium virginicum*, Phenology.

INTRODUCTION

The genus *Lepidium* L. is one of the largest genera of the Brassicaceae (Al-Shehbaz 2012). A cosmopolitan genus of about 175 species It is distributed worldwide, distributed primarily in temperate and sub-tropical regions and poorly represented in the tropics and alpine areas, with some 25 species indigenous in North and Central America, 37 in South America, 47 in Australia, New Guinea and New Zealand, 22 in Africa, and the remainder in Europe, Asia and the Hawaiian Islands (Al-Shehbaz 1986).

Classification within the Brassicaceae usually does not rely on floral characters because the flower structure is so constant. However, in the genus *Lepidium*, there is a tendency for some of the flower parts to be reduced to the point of absence, and hence flower structure is used in subgeneric classification. Fruit and seed characters are valuable too, but the latter tend to have been ignored in *Lepidium*, with the exception of the trifid cotyledon of L. *sativum L*. The characters of vegetative morphology are often used as species-defining characters (Hewson 1981).

L. virginicum can be found occasionally in wild areas, it is more common in developed areas, including fields, pastures, vacant lots, roadsides and railroads, lawns, gardens, and gravelly junkyards, and is typically managed as a weed. The whole plant is known to have health-promoting properties, and decoctions from roots, leaves, or other parts of this species are used extensively in traditional Mexican medicine for the treatment of diarrhea and dysentery, and as a

remedy for renal and liver diseases, abdominal and epigastric pains, and worm infections (Osuna and Lozoya 1989, Argueta Villamar, Cano Asseleih *et al.* 1994, Osuna, Tapia-Pérez *et al*. 2006). *L . virginicum* are usually found on nutrient-rich soils, in railway stations, between the tracks, along roads, on ruderal places, on sands and gravels in harbours, rarely as weeds in crops, entering in composition of the ruderal communities from the orders Sisymbrietalia and Onopordetalia. (Markgraf, 1963). *Lepidium virginicum* is another North American species, widely naturalized in Europe, as well as in Asia (Taiyan *et al*., 2001), South America, Africa, and Australia (SÎRBU, Oprea *et al.*, 2014). According to (SÎRBU, Oprea *et al.*, 2014). *L. virginicum* was introduced in the Botanic Garden of Montpellier, in 1697, and has been recorded in Central Europe as a subspontaneous plant, beginning with the eighteenth century (in 1786). Subsequently, it has gradually spread throughout the continent (Akeroyd and Rich, 2010; (SÎRBU, Oprea *et al.* 2014) Thellung, 1906), mainly along railways.

According to (Lambdon, Pyšek *et al*. 2008), *L. virginicum* is currently one of the most widespread alien plant species in Europe, occurring in more than 80% of European regions. In neighboring countries of Romania, *L. virginicum* was reported in Hungary, in the beginning of the last century (Thellung, 1906), Serbia, in the 1970s (Ivković, 1978), the Caucasus region (Czerepanov, 2007); Vinogradova *et al*., 2010), Ukraine (SÎRBU, Oprea *et al*., 2014) and in Turkey (Terzioğlu and Anşin 2001). In Romania, *L. virginicum* has arrived most probably from Central Europe, along railways, being recorded in 1910, in the North-West of the country (Crişana), near the actual border with Hungary (the Pişcolt village) (Karácsonyi, 1995).

The genus *Lepidium* L. is is distributed worldwide, primarily in temperate and subtropical regions. The genus is poorly represented in Arctic climates; in tropical areas, it grows in the mountains (Al-Shehbaz, 1986). In Egypt, *Lepidium* is represented by4 species L. *latifolium*, *L. sativum*, *L. draba* and *L. aucheri*. The most common ones is *L.sativum*. *L. virginicum* is nonnative in Egypt.

The present study aimed to evaluate the changes in environmental status and distribution range and growth parameters of the new invader *Lepidium virginicum* in the Nile Delta coast. The specific objectives were to analyze of soil properties, monitor phonological changes during life cycle and compare some growth parameters in different habitats of the Nile Delta coast.

MATERIALS AND METHODS

1. Study area

Damietta Province is located in the downstream part of the Damietta branch of the River Nile at 31o 25' 10" north to 31o 48' 54" east N-32o 00' longitude to the north east of the Nile Delta region of Egypt (Figure 1). The coast of Damietta Governorate extends from El-Deeba village (about 20 km from Port-said) to Gamasa at west along the Mediterranean Sea for about 42 Km. This province is bounded by Lake Manzala at the east, Mediterranean sea from the north and El-Dakahlia Governorate from the west and the south. The total average area of Damietta Province is about 1029 Km^2 and the study area is represented in NEW Damietta (Fig1)

Ecological study of the invasive weed *Lepidium virginicum* L. in the fields of the Nile Delta coast

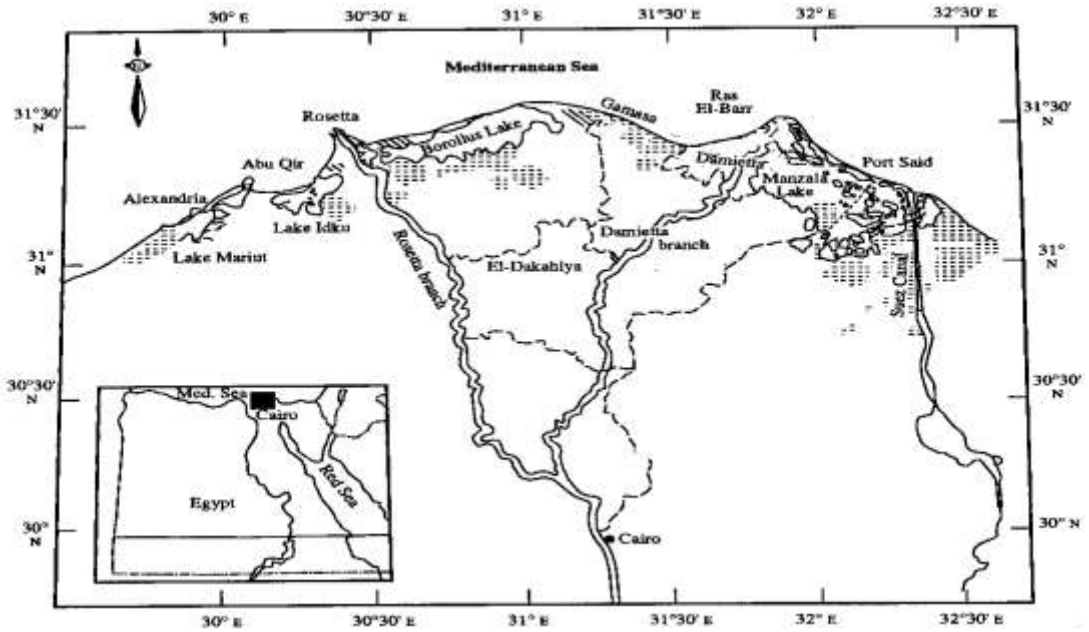

Fig 1. Map showing location of New Damietta in the North Eastern of the Nile Delta.

2. Study species

Lepidium virginicum L.

Annual or biennial, 10–70 cm, single stemmed, branched above. Stem covered with short soft hairs. Basal leaves pinnatisect, 2–13 × 1–4 cm, petiole 1–6 cm, with short soft hairs. Cauline leaves without auricles, linear–oblanceolate, sharply serrate, sparsely pubescent or glabrescent. Sepals white margined 1–1.3 × 0.5–1 mm, sparsely pubescent, yellow–green on middle–upper part. Petals white 1.5–2.1 × 1–1.5. Stamens 2(–3–4), 1.2–1.7mm pedicels erect, 2.2–4.5 mm, pubescent. Siliculae orbicular, winged, 2.5–3.6 × 2.4–3.5 mm, with 1.9–2.7 × 0.3–0.6 mm septum, emarginate at apex, sinus 0.2–0.5 mm wide; style not exceeding to sinus, stigma 0.2–0.3 × 0.1–0.2 mm. Seeds strongly winged, orbicular 1.7–2 × 1–1.3 mm, brown. Flowering time Mar–Jun and fruiting time May-Jul.

Habitats: Roadsides, s.l.–350 m.
Chromosome number: 2n = 16, 32 (22).
Lepidium virginicum is an invasive alien plant in Egypt. It is native of North America; introduced into South America, Europe, Asia, Australia and Africa.

METHODOLOGY

1. Selection of the sites

The different fields in New Damietta were surveyed during 2018 to study the distribution of *L. virginicum*. Twenty stands in Orchards and canal banks fields were selected to record the associated species growing with *L. virginicum* in the different habitats in New Damietta. Identification of species was confirmed using Tackholm (1974) and Boulos (2009).

2. **Field Study**

The fields were visited monthly and weeds grown with *L. virginicum* are recorded in the different habitats. A floristic list is prepared and compared. The growth parameters of *L. virginicum* are monitored monthly as follow:

3. Phenology

Phenological spectrum was constructed based on one year observation. Individual plants (n=10) randomly chosen and marked in the study area. Monthly observation were carried out on the different phonological stages Five phenophases were distinguishes, seedling, vegetative, flowering, fruiting and dieback phases.

4. Morphology

Different growth and leaf forms are recorded monthly and compared during life cycle of *L. virginicum* during the growing season, 2018.

5. Soil sampling and analysis

Soil texture for the studied soils were analysed by using the hydrometer method according to Palmer and Troeh (1995). pH values were determined using a Horizon Ecology Co pH meter Model 5995. The soil salinity expressed as electric conductivity was measured directly using YSI Model 33 S-C-T Meter. The results are expressed as mS/cm. The CaCO3 content was determined according to Jackson (1962). Organic carbon content was determined using the Walkely and Black's rapid titration method as mentioned by Piper (1947).Total Phosphorus was determined using the method adopted by APHA (1992).

6. Data analysis

Two-way ANOVA was used to assess the impact of different sites and different months and their interactions on different growth parameters and chemical composition by using SPSS.

RESULTS

Lepidum virginicum is an annual or biennial exotic herb growing on newly-cultivated land in the Nile Delta coast of Egypt. Twenty stands representing its distribution range in New Damietta and the soil characteristics are studied.

1. Floristic composition

Twenty two species are recorded with *Lepidum virginicum* in the canal bank habitats. The dominant species are *Conyza bonariensis*, *Coronopus didymus* and *Polypogon monspeliensis* (P=60%). In Orchard habitat 12 species are recorded with *Dactyloctenium aegyptium* (P=70%) as dominant species (Table 1).

2. Soil factors

Table (3) presents the mean and standard deviation of some soil variables measured for each of the two habitats invaded with *L. virginicum* in the Nile Delta coast. It is clear that salinity is not important factor in the distribution of *L. virginicum*. The most important factors responsible for the distribution of *L. virginicum* are soil fertility specially nitrogen and phosphorus content in the soil of orchard habitat (Table 2).

Ecological study of the invasive weed *Lepidium virginicum* L. in the fields of the Nile Delta coast

Table 1. Presence percentage of plant species associated with *Lepidium virginicum* in the different habitats of the Nile Delta coast.

Family	Species	Presence (%)	
		Canal bank	Orchards
Amaranthaceae	*Amaranthus viridis*		10
Apiaceae	*Apium Leptophyllum*	40	
Asteraceae	Conyza bonariensis	60	10
	Eclipta alba	10	
	Limbarda crithmoides	10	
	Pluchea dioscoridis	20	
	Pseudognaphlium luteo-album	50	
	Sonchus oleraceus	30	30
	Xanthium spinosum	30	10
Caryophyllaceae	*Spergularia marina*	10	
Brassicaceae	*Lepidium virginicum*	100	100
	Coronopus didymus	60	20
Chenopodiaceae	*Chenopodium album*	20	20
Plantaginaceae	*Plantago major*	10	
Malvaceae	*Malva parviflora*	10	30
Poaceae	*Cenchrus echinatus*	10	20
	Cynodon dactylon	50	20
	Dactyloctenium aegyptium		70
	Polypogon monspeliensis	60	10
Polygonaceae	*Rumex dentatus*	40	10
Portulacaceae	*Portulaca oleracea*		30
Primulaceae	*Anagallis arvensis*	40	20
Ranunculaceae	*Ranunculus sceleratus*	70	20
Scrophulariaceae	*Veronica anagallis*	10	
Urticaceae	*Urtica urens*	10	30
Verbenaceae	*Phyla nodiflora*	20	30

Table 2. Mean, standard deviation (±) of soil characteristics of *Lepidum virginicum* in the different habitats of the Nile Delta coast.

Soil parameter	Habitat	
	Canal bank	Orchard
pH	8.88±0.01	8.87±0.015
EC mS/cm	0.15±0.013	0.14±0.012
HCO3(%)	335.6±27.972	276.19±9.5238
CaCO3(%)	4.5±1.5	1.0±0.5
OC(%)	0.57±0.274	0.61±0.25
N(mg/g)	11.87±3.21	27.93±2.72
P(mg/g)	589.75±78.87	971.04±130.71
Na(mg/g)	0.006±0.0006	0.005±0.0002
K(mg/g)	0.011±0.0006	0.006±0.0002
Ca(mg/g)	0.009±0.001	0.007±0.001
Mg(mg/g)	0.43±0.028	0.30±0.013
Soil moisture(%)	11.4%	10%

3. Phenology

The phonological spectrum during the year observation of *L. virginicum* is shown in Figure (2) Germination of seed and seedling growth occurred during January. Plants grow rapidly and vegetation growth with different leaf morphs appeared during February and March. flowering start in April and extended to the end of July with an average period of flowering of about four month. Fruiting pattern was parallel flowering activity Dieback extended over 4 month period of August to November.

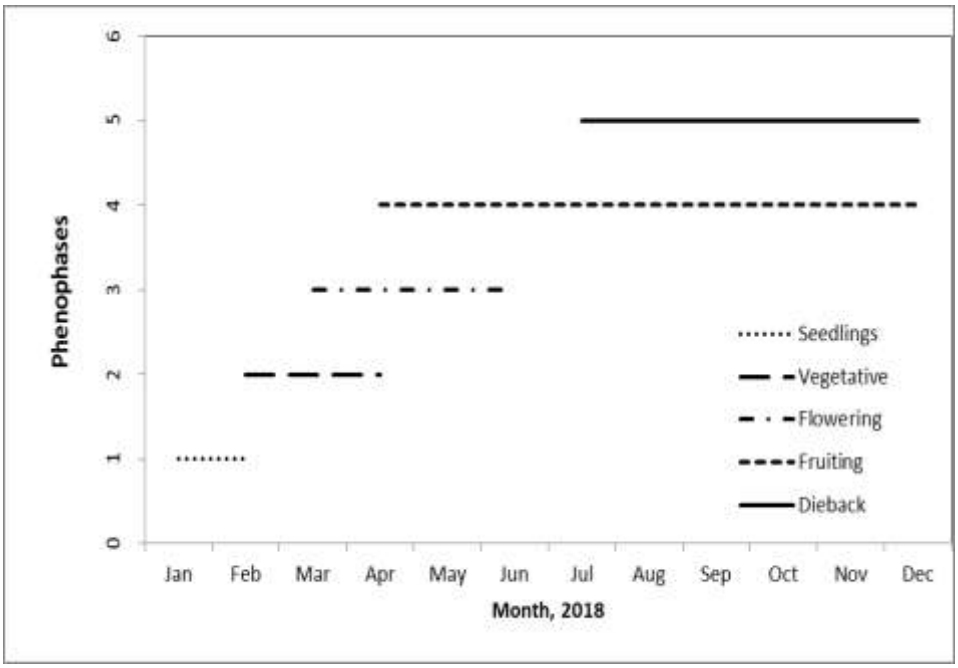

Fig. (2) Duration of plant phenophases in *Lepidium virginicum* in the Nile Delta coast.

4. Leaf forms

Four leaf forms are observed during life cycle of *L. virginicum* in the different habitats of the Nile Delta coast. The four leaf forms are recorded during the early stages of growth, during February and March, in the different habitats (Fig.3). At late stages of growth, during April and May tenuis and simplex leaf morphs dominate the life cycle (Table 3).

Fig. 3. Leaf forms during life cycle of *L. virginicum* in the different habitats of the Nile Delta coast.

Table 3. Means, standard deviation (±) of leaf morphs per plant during life cycle of *L. virginicum*.

Months, 2018	Habitat	Leaf forms			
		Heteris	Rhomboidea	Tenuis	Simplex
February	Canal bank	6.33±0.88	5.33±0.33	19.33±3.28	—
	Orchard	2.62±0.43	22±0.53	23.12±5.26	26±1.15
March	Canal bank	6.5±0.5	17±0.73	18.5±1.5	—
	Orchard	6.5±0.5	8.5±2.5	20±6.5	13±1
April	Canal bank	—	—	38.66±6.96	14.33±2.33
	Orchard	—	—	75±5	24±11
May	Canal bank	—	—	48.5±3.5	12±0.33
	Orchard	—	—	57.5± 2.5	10±0.83

5. Plant height

Plant height was affected significantly by increasing in the age and habitat differences. In Canal bank habitat changes in plant height was increased gradually by increasing plant age from February to March then decreased in May .The highest value was present in March (74 cm) while the lowest was observed in February (18.16cm), respectively (Fig.4).The same pattern was observed in Orchard habitat.

The effects of habitat differences and monthly variation were significant (P< 0.001), also the interactions between monthly variation and habitat differences was significant (P< 0.01) (Table 4).

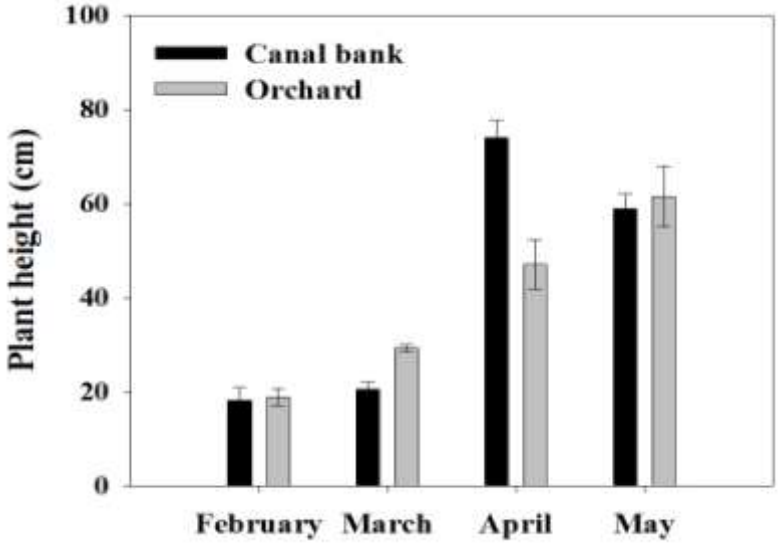

Fig. 4. Monthly variation in plant height of *L. virginicum* in the different habitat, in the Nile Delta coast, 2018.

Table 4: Results of two way ANOVA of morphological traits of *Lepidium virginicum* growing in the Nile delta coast.

Morphological Traits	Site		Months		Site*Months	
	df	F value	df	F value	df	F value
Plant height (cm)	1	20.757***	3	90.009***	3	5.639**
Shoot FW (g/plant)	1	3.377**	3	15.538***	3	9.453**
Shoot DW (g/plant)	1	1.9.257***	3	163.545***	3	133.540***
Root FW (g/plant)	1	26.497***	3	100.139***	3	156.319***
Root DW (g/plant)	1	.403 ns	3	16.497***	3	1.015***

**** =p< 0.01, *** =p< 0.001 , ns = not significant**

6. Shoot Biomass

Shoot fresh weight (SH FW) was affected significantly by increasing the age and habitat differences. In canal bank habitat, the highest value was present in April (32.714 gm/plant) while

the lowest was present in February (15.50 gm/plant), respectively (Fig.5). A similar trend was observed in Orchard habitat. The highest value was present in May (59.320 gm/plant) while the lowest was present in February (8.520 gm/plant), respectively (Fig.5). The effects of habitat differences and interaction between monthly variation and habitat differences were significant (P< 0.01), also monthly variation was significant (P< 0.001) (tab 4).

Shoot dry weight (Sh DW) showed similar trend to that of Sh FW (Fig.4).The effects of monthly variation, habitat differences and interaction between monthly variation and habitat differences were significant (P< 0.001) (tab 4).

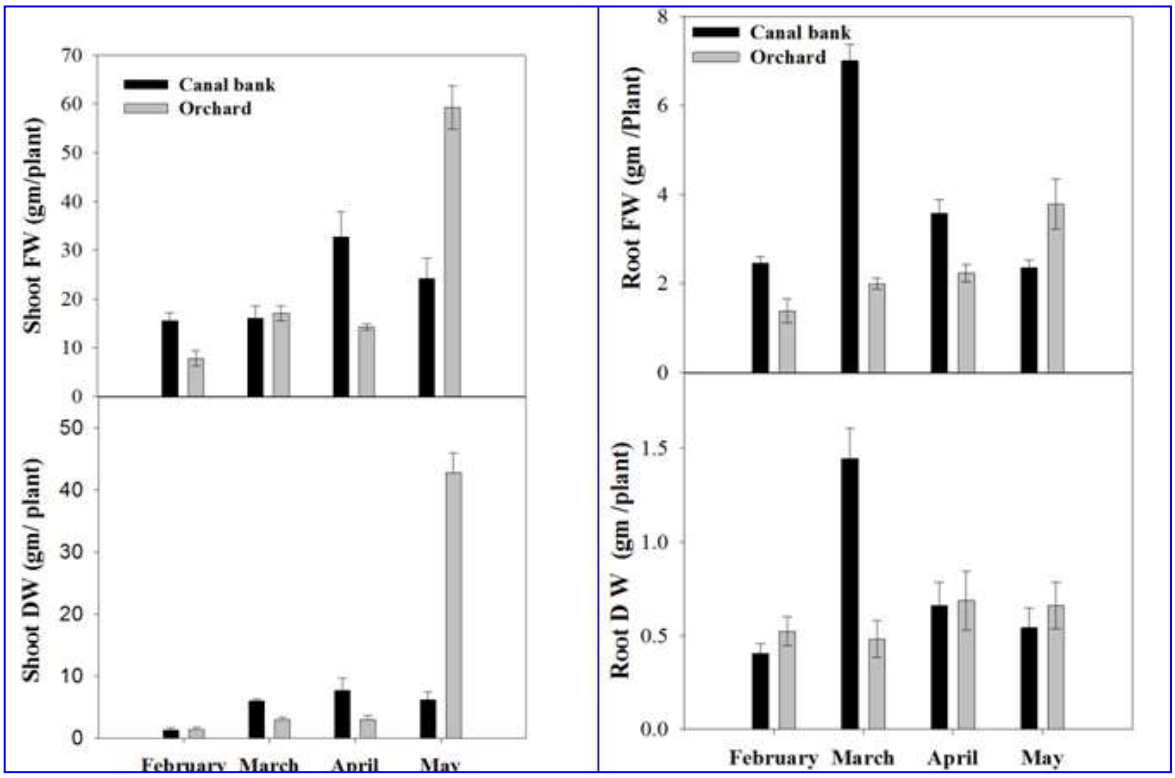

Fig. 5. Monthly variation of Shoot and Root Biomass of *L. virginicum* in the different habitats of the Nile Delta coast, 2018.

6. Root Biomass

Root fresh weight (R FW) was affected significantly by increasing plant age and habitat differences. In Canal bank habitat changes in R FW was varied by increasing plant age, where it increased in March then decreased gradually in April and May. The highest value was present in March (7.00 gm/plant) while the lowest was observed in May (2.34 g/plant), respectively (Fig. 5). In Orchard habitat R FW was increased gradually by increasing plant age. The highest value was present in May (3.78 gm/plant) while the lowest was present in February (1.38 gm/plant), respectively (Fig.5).

The effects of monthly variation, habitat differences and interaction between monthly variation and habitat differences were significant (P< 0.001) (Tab 4). Root dry weight (R DW) was affected significantly by increasing plant age and habitat differences.

In Canal bank habitat R DW was varied by increasing plant age, where it increased in March then decreased in April and May. The highest value was observed in March (7.002 gm/plant) while the lowest was observed in February (2.34 mg), respectively (Fig. 5).

In Orchard habitat R DW was varied by increasing plant age, where it decreased in March then increased in April finally decreased in May. The highest value was observed in April (3.78 gm/plant) while the lowest was observed in March (1.38 gm/plant), respectively (Fig 4). The effects of monthly variation, interaction between monthly variation and habitat differences were significant (P< 0.001) on the other hand habitat differences show no significant (P>0.05) (Table 4).

DISCUSSION

Increased human mobility and disturbance, and altered global geochemical cycles largely explain why exotic weeds are invading ecosystems at unprecedented rates (Vitousek *et al*., 1996). Exotic weeds are invading croplands of Egypt at unprecedented rates. Understanding plant-soil relationships and competitive interactions of invasive weeds is crucial in long-term control strategies. In a field study, we investigated the seasonal and spatial variations of plant growth and distribution of the exotic invasive weed, *Lepidium virginicum* in the Nile Delta coast. *Lepidium* L. is one of the largest genera in the Brassicaceae, consisting of 175 species worldwide (Bowman *et al*., 1999). It is distributed worldwide, primarily in temperate and subtropical regions; the genus is poorly represented in Arctic climates, and in tropical areas it grows in the mountains (Mummenhoff *et al*., 2001). In the last two decades *L. virginicum* is reported as a new invader in the Suez Canal Provinces (Ismailia District), El-Gazzar & Hammouda (2006). Invasion is a community-level process, and the traits of invasive species depend on many factors, including the traits of native species, as well as propagule pressure, and the type and frequency of disturbance and resource limitation. While there is significant variation in results from studies of invasive species conducted in low-resource systems, it is possible to make a few generalizations. With respect to resource conservation, invasive species appear to use nutrients more efficiently than natives in low-nutrient soils. However, invasive and native species are similarly efficient at using water and light in arid and light-limited systems, respectively. With respect to resource acquisition, invasive species tend to have higher R:SH in arid systems and lower R:SH in light-limited systems, relative to co-occurring native species.

L. virginicum has seasonal ecological characters in common, mainly their occurrence in disturbed habitats and similar growth form. The species nevertheless show marked habitat differentiation in relation to water and soil characteristics. The associated species are mainly ruderal weeds with high presence values in orchard than canal bank habitat. Twenty two species are recorded with *L. virginicum* in the canal bank habitats. The dominant species are *Conyza bonariensis, Coronopus didymus* and *Polypogon monspeliensis*. In Orchard habitat 12 species are recorded with *Dactyloctenium aegyptium* as dominant species. This means that the species replacement or biotic exchange is low (Wilson and Shmida, 1984; Shaltout *et al*., 1994).

Environmental variables affecting the distribution and abundance of *L. virginicum* other than human interference (Pieterse *et al*., 1981) are chemical factors of soil. These include: Phophorus and Nitogen (Chavda *et al*, 2017) and man-made habitats (Khedr and Hegazy, 1998). Under field conditions, because of many possible factors are closely inter-related. It is

clear that salinity is less important factor in the distribution of *L. virginicum* in the Nile Delta coast. The most important factors responsible for the distribution of *L. virginicum* are soil texture and fertility, especially nitrogen and phosphorus content in the soil of orchard habitat.

L. virginicum grows rapidly giving different growth forms during life cycle, rosette form during early stages of growth and erect form during late growth stages. Four leaf morphs appeared during life cycle, which enable plants to resist environmental changes. Plants growing in arid and semi-arid systems display a broad range of phenological patterns that limit the severity of water stress (Williams *et al*., 1997; Sandquist and Ehleringer, 1998). Annual species are common in arid systems, because this strategy enables them to complete a short life-cycle during the favorable wet season.

Phenological patterns also correlate with plant function. In the Sonoran Desert, Kimball et al. (2011) found that annual species with high WUE, including the invasive forb *Erodium cicutarium*, germinate earlier in the growing season and reproduce for a longer time period. Species with low WUE germinate later, following several rainfall events, but the plants experience higher risk of mortality associated with warmer temperatures later in the growing season.

L. virginicum is an ideal competitor (Grime 1977); it grows rapidly, it is a prolific seed producer, and can rapidly expand by budding rootstock. Moreover, its ability to spread and form dense monocultural stands which retard light penetration to the soil surface would be another competitive advantage (Radosevich and Holt 1997). Our data, however, hint at a limitation to its competitiveness.

Results of biomass allocation (fresh and dry weight) to the different plant parts and plant height indicated that, the growth parameters of *L. virginicum* was affected significantly by increasing the age and habitat differences. The effects of global change factors and their interactions on invasive species are still largely unresolved, and more research is needed on this important topic. Understanding the physiological mechanisms by which native and invasive species respond to current and future resource availability will help restoration efforts. Specifically, leaf- and plant-level traits can suggest ways to manipulate community-level properties to restore invaded ecosystems. This is the first step to shed light on the ecological aspects as well growth parameters of *L. virginicum*. Further studies are needed on functional attributes and chemical composition of this new invader.

In conclusion, the study this new invader weed in the coastal area of the Nile Delta is urgently required. The present study is the first step to shed light on the ecological aspects as well as growth parameters. Further studies are needed for *Lepidium virginicum* L.

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دراسة بيئية على نبات الرشاد والغازي حديثا للحقول بساحل دلتا النيل

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المستخلص

اظهرت الدراسات البيئية و التحليل الفلورى عن الانواع الغازية حديثا بمصر بوجود نبات الرشاد في محافظة الاسماعلية (الجزار وحمودة 2006). وفي هدة الدراسة تم اكتشاف وجود نبات الرشاد في حديقة الفاكهة وعلى حواف قنوات الحقول بالأراضي الزراعية (بمنطقة دمياط الجديدة) ساحل دلتا النيل . كما تم تسجيل الانواع المرافقة مع نبات الرشاد وتحليل عينات التربة للتعرف على خصائصها الكيميائية والفيزيائية . و من خلال دراسة بيئة مكتفة للشكل الظاهري للنبات وكدلك اشكال الورقة الخضرية في النبات خلال مراحل النمو المختلفة تبين وجود اربعة اشكال من الاوراق , وكدلك اظهرت الدراسة خصوبة التربة وبخاصة تركيز النيتروجين والفسفور كان لها دور هام في توزيع ونمو النبات . وعلى الرغم من التوزيع المحدود لنبات الرشاد بمنطقة الدراسة وفي المناطق الاخرى من مصر , فإن احتمالات انتشاره سوف تكون سريعة لقدرة النبات على إنتاج كميات كبيرة من البذور وصغيرة الحجم والتي تغزو بساتين الفاكهة .النتائج المتحصل عليها سوف تفيد في الادارة لكي تمكن هدا النوع الغازي للحقول المزروعة بالمنطقة الساحلية لدلتا النيل.