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Phenotypic Plasticity of Four Invasive Species in North-Eastern Section of the Nile Delta Coast, Egypt

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Abstract

One of the essential mechanisms through which plants can adapt to prevailing environmental conditions is phenotypic plasticity. To explain the invasive success across the invaded new areas, the phenological pattern and vegetative features of the exotic species are investigated. The four exotic weeds included in this study are *Xanthium strumarium* L., *Bassia indica* (Wight) A. J. Scott, *Atriplex lindleyi* Moq., and *Trianthema portulacastrum* L.

Results indicated that shoot length was greatest in *X. strumarium*, followed by *B. indica* and *A. lindleyi* but least in *T. portuiaeustrum*. Fresh weight of the foliage was comparable in *X. strumarium and A. lindleyi*, being higher in both than in *B. indica* and *T. portulacastrum.* Dry wight of the foliage was highest in *X. strumarium*, followed by *A. Lindleyi*, but it was least with comparable values of *B. indica* and *T. portulacastrum*. Water content of shoots was higher in *T. portulacastrum* and *B. indica*, slightly lower in *X. strumarium* and least in *A. lindleyi*.

The highest concentrations of P (0.620.02), K (0.060.001), and Mg (24.763.79) were found in site 2 of *T. portulacastrum*. The highest levels of N (6.070.30), Na (0.200.009), and moisture content (44.320.40) were found in site 3 for *B. indica*. The components with the lowest concentrations were P (0.100.01), K(0.010.0003), Mg (0.370.01), and Na (0.040.003) in *A. Lindleyi* at site 4, whereas N (2.171.00) and moisture content (17.215.10) were the lowest in *X. strumarium* at site 1.Analysis of variance revealed significant (P<0.05) to very highly significant (P<0.001) variation in growth parameter among the studied plant species. Based on the magnitude of the F ratio, the variability was most evident in shoot dry weight, followed by shoot fresh weight and water content but was relatively low in number of leaves, number of branches and water content of shoot. Based on the obtained results, it can be concluded that the four exotic weeds can successfully invade new areas by changing their phenological plasticity. The optimal management and control measures of these exotic weeds will benefit from this.

Keywords: Biological invasion, environmental factors, exotic weeds, growth parameters, phenotypic traits.

Introduction

Weeds that are intentionally or accidentally introduced outside of their normal habitats and then establish themselves, multiply, and spread outward while inflicting environmental problems are known as invasive alien species (IAS) **(Shiferaw et al. 2018)**. The second biggest threat to the world's biodiversity, behind habitat degradation, is caused by these species' competition with native plants. According to **Richardson *et al.* (2000)** and **Daehler (2003, Khedr et al. 2023),** invasive plants are those that have been introduced to the ecosystem where they have altered the habitats and can reproduce successfully outside of their ecological range. Hess *et al*. (2019) claim that as anthropogenic activity increases, disruptions are created that encourage the spread of invasive plants at the expense of native ones. Invasive plants have the capacity and reduce the available space for native species to survive (Catford, 2012). After habitat degradation, these species provide the second greatest threat to the world's biodiversity because they compete with local species for food and habitat, resulting in biodiversity loss.

Anccording to Richardson et al. (2000) and Daehler (2003), invasive plants are those that can effectively reproduce outside of their ecological range and have been introduced to new habitats where they have altered all prevailing environmental factors. Hess et al. (2019) claim that the increase in human activity results in disturbances that encourage the expansion of invasive weeds at the expense of native ones. The capacity of invasive plants increases their ability to thrive, which in turn reduces the available habitat for native species (Catford, 2012).

X. strumarium is an invasive weed (Everitt et al. 2007, Khder et al. 2023), it is a member of the Asteraceae family. One of the genera included in the Amaranthaceae family is *Bassia* All (Grabowski et al. 2023), it is a native annual herb or perennial subshrub of Eurasia and Africa. The Amaranthaceae family includes *A. lindleyi*, also referred to as Lindley's saltbush. In Egypt's desert settings, this native Australian plant is extremely prevalent. (Täckholm, 1974; Bolous, 2009). Invasive species are also well-known to exist in California, USA (Milton et al., 1999). *T. portulacastrum*, which is also known as horse purslane and is primarily found in orchards, farms, and desert plains, is another invasive species. *T. portulacastrum* is a native of South Africa and belongs to the Aizoaceae according to Kaur and Aggarwal (2017).

This study's objective was to evaluate the phenological plasticity of four exotic weedson the Nile Delta coast. It will be explored how this plasticity affects their ability to successfully colonized new areas.

Materials and Methods

Study area

The Nile Delta region of Egypt is to the north-east of Damietta, which is situated in the downstream section of the Damietta branch of the River Nile at 31° 25' 10'' north to 31° 48' 54'' east N-32 0 00' longitude (Zahran and Willis, 2009). The coastline of Damietta stretches along the Mediterranean Sea for about 42 kilometers from the settlement of El-Deeba (about 20 km from Port-Said) to Gamasa in the West. Lake Manzala to the East, the Mediterranean Sea to the north, and El-Dakahlia to the West and South border this province (Figure 1).

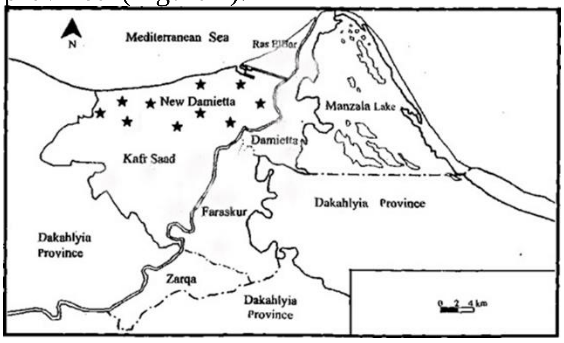

Figure (1): Location map of the study area showing the different sites where the four exotic weeds and soil samples were collected

Climate

The climatic normal are shown in Table 1 and were taken from the Agro Meteorological Annual Report of Egypt (1999). In January and August, the mean maximum air temperature ranged from 18.4 to 31.3 ºC, while in those months, the mean minimum temperature ranged from 8.2 to 21 ºC. In January and August, the monthly mean air temperature varied from (13.3-26.3°C). In the study area, November to

February had the heaviest rainfall; summer is essentially dry. During the winter months of June and December, the highest quantities (0.2 and 24.7 mm) were recorded. In May and June, relative humidity ranged from 69.0% to 84.0%; in December, it was 84.0%. Numerous bodies of water, such as the River Nile, northern lakes, and the Mediterranean Sea, as well as dense transpiring vegetation, all contribute significantly to raising the values of these climatic normals. In December, there was little evaporation (2.8 mm per day).

Table (1): Climatic data along the study area R.H= Relative Humidity, ETo= Evapotranspiration (Egyptian annual report, 1999)

Parameters	**Month**											
	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min. Temp. (°C)	8.5	6	9.2	12	16	19	21	22	20	17	14	11
Max. Temp. (°C)	18	27	20	26	26	30	31	32	31	29	25	20
R.H%	84	80	78	75	73	73	77	79	75	75	79	77
Wind speed (m/s)	4.5	5.7	6.3	6.3	6	5.9	4.7	4.4	4.4	4.3	4.3	4
Mean rainfall	12	trace	27	trace	12	trace	trace	trace	trace	trace	trace	trace
ET_o (mm/day)	1.5	2.3	2.5	4.2	4.6	6.6	6.1	5.2	4.8	3.9	2.3	1.8

Morphological characteristics

The following morphological characteristics are recorded for each plant: total plant fresh and dry weights, shoot length, shot fresh and dry weights, water content, number of branches, and number of leaves.

Soil sampling and analysis

Extraction of the mineral content of soil and plants

For the purpose to extract the soil's soluble minerals, a known quantity (10 g) of the dry soil was added to 50 ml of water in a 100 ml conical flask, and the mixture was shaken for one hour using a Lab-Line Model No. 3521 orbital shaker. After filtering the combination, the amount of minerals was found in the extract.
Before to being digested by the sulfuric acid/hydrogen peroxide process of Allen et al. (1989), a known weight of the dried plant material was crushed into a fine powder to extract the total mineral content of the plant. In a one-liter flask, 0.42 g of selenium and 14 g of hydrated lithium sulfate were combined to create the digestion mixture. 350 ml of H2O2 H_2O_2 (100 volume) and 420 ml of concentrated H2SO4 H_2SO_4 were gradually added to the mixture while cooling. In a Kjeldhal digestion flask, 50–100 mg of litter was introduced along with 5 ml of the digestion mixture. To stop the white vapor r from escaping, the digesting flasks were gradually heated. The extract was prepared up to 50 ml in a volumetric.

Determination of the mineral composition of soil and plants

Using the John (1970) method, the phosphorus concentration of the clear extract was measured Spectro-Photometrically. Using the standard methods of APHA (2017) direct Nesslerization method, nitrogen content was calculated. Using a PFP-7 flame photometer, the amounts of K, Na, and Ca in the clear extracts were calculated.

Statistical Analysis

ANOVA was carried out using SPSS 21.0 software (IBM, 2012). Forward to determine some nutrients (Mg, Na, K, N and P) characteristic that have the most significant effect on the plants and soils samples.

Results and Discussion

The environment can cause changes in plant behavior at a morphological or physiological level. Such changes are vital for the survival of intrusive weeds beneath heterogeneous and variable conditions (Gauvrit and Chauvel, 2010, Catoni et al. 2012). The understanding of phenotypic versatility will be significant for anticipating changes in species dissemination, community composition, and the victory of intrusion beneath worldwide alter conditions.

Phenotypic traits

Phenotypic versatility, naturally initiated variety within the development and improvement of outlandish weed (Scheiner, 1993), enable presented species to outlive and flourish in variable situations by altering their morphology to coordinate living space conditions (Richards et al., 2006). It will take extensive research to ascertain whether the features of some of the most effective invasive weeds exhibit high degrees of adaptability. According to recent studies, alien plants are more plastic than native ones. According to a meta-analysis by Davidson et al. (2011), non-invasive plants were better able to sustain fitness homeostasis in stressful and resource-constrained environments than invasive species among species pairs. In the invasion stages, phenotypic flexibility provides a competitive advantage (Dietz and Edwards, 2006).

X, strumarium had the longest shoots, followed by *B. indica* and *A. lindleyi*, but *T. portulacastrum* had the shortest shoots (Table 2 and Figure 2). In both *X. strumarium* and *A. lindleyi*, the fresh weight of the leaves was equivalent and greater than in *B. indica* and T. *portulacastrum*. *A. lindleyi* and *Xanthium* had the heaviest dry weight of leaf, while *B. indica* and T. *portulacastrum* had comparable values. *T. portulacastrum* and *B. indica* had comparable high foliage water content, *X. strumarium* had a little lower level, and *A. lindleyi* had the lowest level. The inter-species variability in foliage water content was significantly significant even though the absolute values of the different species' water content were quite near to one another. According to Shaltout et al. (2013) analysis of *T. portulacastrum*'s growth patterns and distributional patterns in the Nile Delta, the species' proliferation could result in a serious ecological catastrophe. The phenotypic plasticity of the species can aid in the invasion of *T. portulacastrum* if there are considerable changes (Ellmouni et al., 2021). Results of analysis of variance revealed significant ($P<0.05$) to very highly significant ($P<0.001$) variation in growth parameter among the studied plant species. Based on the magnitude of the F ratio, the variability was most evident in shoot dry weight, followed by shoot fresh weight and water content but was relatively low in number of leaves, number of branches and water content of shoot (Table 3). The number of branches was highest in *B. indica* , followed by and *A. lindleyi* and *T. portulacastrum* and least in *X. strumarium*. The number of leaves per plant was highest in *A.lindleyi* and by far higher than in the other three species (*B. indica*, *T. portulacastrum* and *X, strumarium*) which exhibited low comparable values.

Plant chemical composition

Magnesium content of shoot was greatest in *T. portulacastrum*, followed by *X. strumarium*, and *A. lindleyi* (with comparable magnitudes) but least in *B. indica* (Table 4 and Figure 2). Despite the limited variability in P content of shoot results revealed that P content of the shoot was highest in *T. portulacastrum*, followed by *X. strumarium*, and *B. indica* (with comparable magnitudes) but least in *A. lindleyi* (Table 5 and Figure 2). Na content of tshoot was relatively high in *T. portulacastrum* and *A, lindleyi*, a bit lower in *B. indica*, and least in *X. strumarium* (Figure 2). On the other hand, K content of shoot was relatively high in *T. portulacastrum* and *X. strumarium*, a bit lower in *B. indica*, and least in *A. lindleyi* (Table 5 and Figure 2). Following the K content of shoot, was highest in *X. strumarium*, by far lower in *T. portulacastrum* and *B. indica* but least in *A. lindleyi* (Table 5 and Figure 2). In contrast to the K content of shoot, shoot N content was highest in *A. lindleyi* relative to the other three species which attained comparable N contents.

Chemical composition of soil supports the four exotic weeds

Analysis of variance revealed significant ($P<0.05$) to very highly significant ($P<0.001$) variation in mineral composition of soil among the studied sites. Based on the magnitude of the F ratio, the variability was most evident in Na content, followed by K content but relatively low in the contents of P, N (Table 4).

Phosphorus content of soil was highest at site 2, followed by site 3 and site 1 but least at site 4 (Table 4). Water content was comparable and high at sites 2, 3, and 4 but least at site 1. e Sodium content of soil was highest at site 3, followed by site 2 and but least at sites 1 and 4. Potassium content of soil was higher at sites 2 and 3 than at sites 1 and 4.). Similar to K content, N content of soil was higher at sites 2 and 3 than at sites 1 and 4. Similar to P content, Mg content of e soil was highest at site 2, followed by site 3 but least at sites 1 and 4.

Table (2): Morphological characteristics of the four invasive species. Each value is the mean of three replicates ± SE. Meanfollowed with the same latter are non-significant P<0.05.

Plant species	Shoot length (cm)	Shoot FW (g/plant)	Shoot DW (g/plant)	Water content (% FW)	Number of branches	Number of leaves
Xanthium strumarium	74.0 ± 12.1^{a}	70.6 ± 9.78^{ab}	13.41 ± 1.53^{ba}	80.9 ± 0.50^{c}	6.67 ± 0.33^{dc}	8.00 ± 0.58^{dc}
Tranthema. portulacastrum	23.3 ± 1.20^{c}	26.8 ± 9.78^{c}	3.423 ± 1.53^{dc}	87.3 ± 1.32^{a}	8.67 ± 2.91^{cb}	19.0 ± 1.53^{b}
Bassia indica	51.3 ± 6.44^{ab}	24.6 ± 9.78^{cd}	3.630 ± 1.53^{cd}	86.2 ± 2.41^{ab}	22.0 ± 1.00^{a}	13.7 ± 0.67^{cb}
Atriplex lindleyi	41.3 ± 2.03^{bc}	71.9 ± 9.78^{a}	20.64 ± 1.53^{ab}	71.1 ± 1.01^{d}	14.3 ± 2.67^{b}	60.3 ± 22.4^{a}

Table (3): Results of One-way ANOVA summarizing the interspecies variability among the growth of four investigated weeds.

Variable	Sum of Squares	df	Mean Square	F	Sig.
Shoot Length	4017	3	1339	9.203	0.006
Shoot fresh weight	6238	3	2079	17.39	0.001
Shoot dry weight	625.2	3	208.4	54.24	0.000
Water content	492.6	3	164.2	24.82	0.000
Number of branches	424.9	3	141.6	11.33	0.003
Number of leaves	5104	3	1701	4.509	0.039

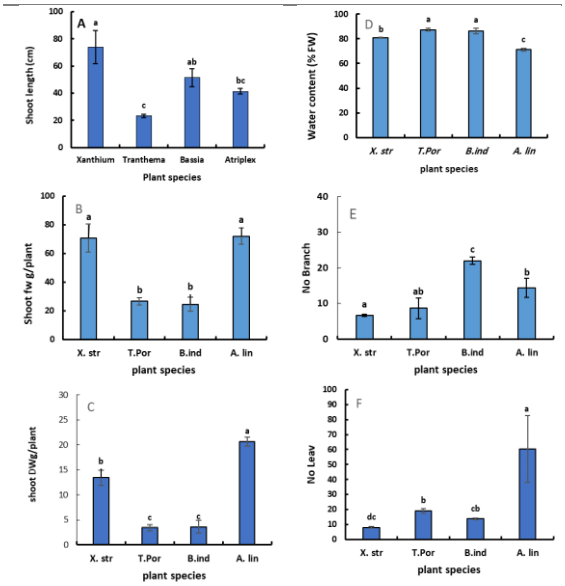

Figure (2): Phenotypic traits of the four invasive species. (A) shoot length, (B) shoot fresh weight, (C) Shoot dry weight, D Water content, E Number of branches, F Number of leaves Each column represents the mean of three replicates ± SE. columns with the same latter are non-significant P<0.05.

Table (4): Soil variables support the soil of the four exotic weeds.

Soil parameter	Site1	Site2	Site3	Site4
P mg/g	0.27± 0.05 ^{bc}	0.62 ± 0.02^{a}	0.48 ± 0.18^{ab}	0.10 ± 0.01^{cd}
N mg/g	2.17 ± 1.00^{c}	6.04 ± 0.6^{ab}	6.07 ± 0.30^{a}	2.99 ± 0.07^{c}
Na mg/g	0.05 ± 0.003^{c}	0.10 ± 0.002^{b}	0.20 ± 0.009^{a}	0.04 ± 0.003^{c}
K mg/g	0.02 ± 0.0009^{c}	0.06 ± 0.001^{a}	0.05 ± 0.005^{ab}	0.01 ± 0.0003^{c}
Mg mg/g	2.41 ± 0.16^{bc}	24.76 ± 3.79^{a}	7.87 ± 0.68^{b}	0.37 ± 0.01^{c}
Moisture content (%)	17.21± 5.10^{d}	38.23 ± 0.52^{abc}	44.32 ± 0.40^{a}	38.31 ± 4.27^{ab}

T. portulacastrum showed the highest concentration of P in site2 (0.62± 0.02), K (0.06±0.001) and Mg (24.76±3.79). *B. indica* in site3 showed the highest concentration of N (6.07±0.30), Na (0.20±0.009), Moisture content (44.32±0.40) (Table 4.) The lowest concentration of elements was recorded in *A. Lindleyi* in site 4 of P (0.10±0.01), K(0.01±0.0003), Mg (0.37±0.01) Na (0.04±0.003), *X.strumarium in site1* showed the lowest concentration of N (2.17±1.00), Moisture content (17.21±5.10).

Table (5): Chemical composition of the four invasive species in the eastern-east of the Nile Delta coast. Each value is the mean of three replicates ± SE. Means followed with the same latter are non-significant t P<0.05.

Item	*X. strumarium*	*T. Portulacu-strum*	*B.indica*	*A. llindleyi*
P mg/g	4.51 ± 0.94^{ab}	6.12 ± 1.31^{a}	4.17 ± 0.81^{bc}	2.53 ± 0.15^{c}
N mg/g	10.05 ± 1.065^{a}	9.43 ± 1.482^{a}	10.14 ± 1.413^{a}	39.68 ± 6.922^{b}
Na mmol /g	0.44 ± 0.007^{c}	1.64 ± 0.025^{a}	1.27 ± 0.106^{b}	1.53 ± 0.113^{a}
Kmm ol/g	0.84 ± 0.030^{a}	0.86 ± 0.053^{a}	0.64 ± 0.079^{b}	0.27 ±0.022^{c}
Mg mg/g	3.77 ± 0.25^{bc}	7.91 ± 0.60^{a}	1.60 ± 0.21^{d}	4.07 ± 0.68^{b}

T. portulacastrum showed the highest concentration of Mg (7.91 ± 0.60a), P (6.12 ± 1.31), Na(1.64 ± 0.025) and K (0.86 ± 0.053). *A. lindleyi* showed the highest concentration of N (39.68 ± 6.922). The lowest concentration of elements was recorded in *Bassia indica* Mg (1.60 ± 0.21). *Atriplex lindleyi* showed the lowest concentration of P (2.53±0.15), K (0.27±0.022), *T. portulacastrum* showed the lowest concentration of N (9.43±1.482) *X. strumarium* showed the lowest concentration of Na (0.04±0.003).

Conclusion

Future- oriented studies on exotic weeds in order to understand the response to environmental fluctuations including climate change. There is the necessity to analyze variations at phenotypic traits as well as genetic levels for the same species in particular, for exotic weeds because these could have drastic effects on the ecosystem.

Conflict of interest

The authors declare no conflict of interest.

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الملخص العربي

عنوان البحث: المرونة المظهرية لأربعة أنواع غازية في القسم الشمالي الشرقي لساحل دلتا النيل ، مصر

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يهدف البحث الى دراسة المرونة المظهرية إحدى الوسائل الرئيسية التي يمكن للنباتات من خلالها التعامل مع الضغوط البيئية السائدة. يتم استكشاف النمط المظهرى والسمات الخضرية للأنواع الغازية للوقوف على مدى نجاح النباتات الغازية عبر الموائل التي تم غزوها. تساهم هذه الدراسة في تقييم المرونة المظهرية لأربعة أعشاب غريبة مختارة وهي: الشبيط Xanthium strumarium L.، الكوخيا Bassia indica (Wight) A. J. Scott، و التربلكس نوع لنديلى Atriplex lindleyi Moq ونبات تريانثيما Trianthema portulacastrum L.

اظهرت النتائج إلى أن طول الساق كان أكبر في X. strumarium ، يليه B. indica و A. lindleyi ولكن أقل في نبات تريانثيما T. portulacastrum. كان الوزن الطازج للأوراق مشابهًا في X. strumarium و A. lindleyi ، حيث كان أعلى في كل من B. indica و T. portulacastrum. كان الوزن الجاف للأوراق أعلى في X. strumarium ، يليه A. lindleyi ، لكنه كان أقل مع قيم مماثلة لـ B. indica و نبات تريانثيما T. portulacastrum. كان المحتوى المائي للبراعم أعلى في T. portulacastrum و B. indica ، وأقل قليلاً في X. strumarium وأقل في A. lindleyi.

أظهرنبات تريانثيما T. portulacastrum أعلى تركيز للفوسفور في الموقع ٢ (0.62 ± 0.02) و K (0.06 ± 0.001) و Mg (24.76 ± 3.79). أظهرت الكوخيا في site3 أعلى تركيز للنيتروجين (6.07 ± 0.30) ، الصوديوم (0.20 ± 0.009)، محتوى الرطوبة (44.32 ± 0.40). تم تسجيل أدنى تركيز للعناصر في A. lindleyi في الموقع ٤ من P (0.10 ± 0.01) ، K (0.01 ± 0.0003)، Na (0.04 ± 0.003) Mg (0.37 ± 0.01)، X.strumarium في الموقع ١ أظهر أدنى تركيز N (2.17 ± 1.00)، محتوى الرطوبة (17.21 ± 5.10).

أظهر تحليل التباين تباين معنوي (P <0.05) إلى تباين معنوي عالي (P <0.001) في معامل النمو بين الأنواع النباتية المدروسة. بناءً على حجم نسبة F ، كان التباين أكثر وضوحًا في الوزن الجاف للساق، يليه الوزن الغض للبراعم ومحتوى الماء ، ولكنه كان منخفضًا نسبيًا في عدد الأوراق وعدد الأفرع ومحتوى الماء للساق.

لذا، نستنتج أن الحشائش الأربعة الغازية يمكن أن تغزو موائل جديدة مع تحول في المرونة المظهرية مما يجعل عملية الغزو ناجحة. النتائج المتحصل عليها ستكون مفيدًة لإدارة ومكافحة هذه الحشائش الغازية وبالذات بالمناطق المحمية.