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Phenotypic Plasticity Among Ecological Populations of *Polygonum equisetiforme* Sm. in the Northern Geographical Areas, Egypt

Laila M.M. Bidak, Mohamed S. Abd El-Razik and Eman T. El-Kenany
Department of Botany, Faculty of Science, University of Alexandria, Egypt

Abstract: The main objective of present study is to provide some clue on how the different populations of *Polygonum equisetiforme* species respond to different environmental conditions. Plant individuals were chosen from 22 sites representing different geographical areas: The western section, Nile Delta and north Sinai. Ripe seeds were collected from the sampling sites. Soil analyses were performed to collected soil samples from each site. Preliminary germination experiments were conducted to determine the optimum conditions for germination of seeds. Two *ex situ* cultivation experiments were carried out in two successive years under uniform conditions. Morphological and seed attributes have been measured for the wild populations and the cultivated progenies. Protein content of seeds and seed coat morphology as well as the anatomical structure of the different organs of the investigated species were also studied. Germination experiments showed that seeds of *Polygonum equisetiforme* Sm. require a storage period before starting to germinate for most sites, while further variability in germination percentages did occur with extending the storage period of seeds. This period exceeded two months for active germination of seeds representing most of the sites. The present study points out many important remarks, of which: population of Nile Delta section exhibited the most plastic response among different conditions; Seed size and reserve of *P. equisetiforme* are environmentally induced rather than genetically fixed characters. Seed coat is characterized by two patterns of ornamentation, wavy and papillate, the wavy ornamented is more frequent. Electrophoresis separation of protein bands in the sampled of *Polygonum equisetiforme* showed that all samples has the same protein bands. This may reflect the consistency of the same kinds of protein and suggests the absence of genetic variation within different individuals collected from different geographical areas. It also reveals that the protein pattern of the study species tends to be genetically fixed. Wild and cultivated progenies of the western province showed tendency of their individuals to contain the highest amount of protective tissues in their leaves; supporting tissues in their stems and conductive tissues in their roots. This probably reflects the great response of this population to environmental conditions. Fluctuation in the thickness of these tissues in the cultivated progenies leads to the assumption that thickness of layer is an environmentally affected. However, arrangement of layers in *Polygonum equisetiforme* is mostly genetically fixed as they exhibited the least change affected by the environmental changes. There was a plastic response in the timing of flowers production for the plants of the *ex situ* experiments to ensure faster reproduction and complete life history in the new environment. Meanwhile, wild individuals produce a large number of flowers to encounter numerous interacting stresses for survival. The present study also showed that individuals of *P. equisetiforme* allocate resources to support vegetative growth rather than reproductive output in the successive progenies in response to *ex situ* cultivation.

Key words: Phenotypic plasticity, *ex situ* experiments, environmentally induced, progeny

INTRODUCTION

Some types of phenotypic changes, especially those elicited by resource limitation, may represent inevitable response to adverse conditions (Smith-Gill, 1983); but other types of plasticity may better equip a single genotype to survive and maintain reproductive fitness when faced with fluctuating environments (Sultan, 1995). Only recently has plasticity been widely recognized as a significant mode of phenotypic diversity and hence as an important aspect of how organisms develop, function and evolve in diverse environments. Now, phenotypic plasticity is widely recognized as a major source of variation in nature (Sultan, 2001).

Differences in morphological variability as well as seed production are known to occur between populations

Corresponding Author: Laila M.M. Bidak, Department of Botany, Faculty of Science, University of Alexandria, Egypt

of many species. Such interspecific variability is assumed to be of adaptive significance and to affect population fitness, particularly in species inhabiting fluctuating, unpredictable environments (Schlichting, 1986).

Plastic reproductive timing and allocation have been documented in many herbaceous species (Pigliucci, 1997; Sultan, 2001; Galloway, 2005). Plants might respond to environmental conditions not only by adjusting their own phenotypes but also by altering those of their offspring, through changes in the quantity and quality of seed provisioning and in the structure of biochemistry of the seed coat and fruit tissues (Galloway, 2001).

Polygonum equisetiforme Sm. is a glabrous perennial herb, sometimes woody at the base and reaches a height up to 100 cm. Stems are numerous and often richly branched, procumbent, rarely ascending or erect. Anther contains radio symmetric pollen grains with tricolporate aperture. Achene is about 3 mm, ovoid or triquestrous (Boulos, 1999). Flavonoids, different enzymes and their inhibitors have been isolated from the species. The use of *Polygonum* species as food for man and animals has been reported in different parts of the world (Zahran and Willis, 1993).

The wide range of variations in morphology and the habit of growth supported choosing Intraspecific comparisons between populations of *P. equisetiforme* Sm. as the subject of the present study that aspires to investigate the addressed questions:

1: Which plant populations of the different geographical areas show more plasticity in response to various environmental conditions?
2: How do local adaptation and individual tolerance contribute to the distribution and abundance of the study species?
3: How do plants from different geographical areas respond to different environmental conditions?
4: How fast do plants from different habitats reach reproductive maturity when cultivated?
5: Do materials raised from *ex situ* seed typically resemble wild plants of the habitats samples? and 6- Is phenotypic plasticity a character-specific or a genotype-specific attribute?

MATERIALS AND METHODS

The study area: Twenty-two sampling sites (Table 1) are distributed in provinces representing the western section of the Mediterranean coastal land of Egypt (WP and EP), the Nile Delta (ND) and North Sinai sections (NS). These sites represent most of the northern Egyptian geographical areas. These areas are characterized by subdesertic warm climate (UNESCO (1977), have different soil types and features and different habitats.

The Mediterranean coastal land, in general, belongs to the dry arid climatic zone of Koppen's (1931) classification system. In the present study, the western section of the Mediterranean coastal land is divided into two provinces; the first is the Western Province (WP) which extends from El-Kasr to Alamin. The second is the Eastern Province (EP), which extends from Omayed to Maamora (Table 1). The main soil group of this area are yarmosols and eutric regosols. Yarmosols are clay loam and sandy loam in texture. Eutric regosols are sand deposits, several meters in thickness and remarked by wind action.

The Nile Delta section (ND including sites of El-Bousseli, Edfina, Rosetta, Damanhour, Tanta, Mansora, Ras El-Bar and Damietta. The climate belongs to the Mediterranean zone. The selected sites of this region lies in the arid region which characterized by warm summer and mild winter. Soil is mostly heavy in the texture and rather compact at the surface.

The eastern section is designed as the north Sinai section (NS). This section is presented by El-Arish airport site in the present study, where the studied species was present.

Two groups of *Polygonum equisetiforme* Sm. each of five mature plant individuals were collected from each site. Plants of the first group were cleaned, pressed dry and prepared for morphological study. Individuals of the second group were separated to different organs (roots, stems and leaves) and were kept in 5% ethanol ready for studying the anatomical structure. Ripe seeds were also collected from the sampling sites along the other plant material. Seeds were dried at room temperature, placed in dry paper bags and used to study seed shape and coat morphology; protein content and *ex situ* experiments to compare phenotypes of the wild populations with the cultivated progenies.

In each sampling site, three composite soil samples (0-50 cm depth) were collected, air-dried and sieved. Soil water extracts of 1:5 v/v were prepared and used for the determination of pH, Electric Conductivity and the total organic matter (Allen *et al*., 1974). Calcium carbonate percentage was determined using Collins Calcimeter described by Kershaw (1973). Boyoucos hydrometer method was applied to determine the percentages of sand, silt and clay in the soil samples.

Germination experiments: Three sets of seeds (each of 25 seeds/site) were used to determine the suitable temperature for germination (30, 15 and below 10°C). The duration of these experiments ranged from 10 to 14 days. Germination experiments were conducted directly after the collection of seeds from their natural habitats and it was repeated five times under the same regimes after one, two, three, six and nine months from the date of seed collection respectively to determine the best time for cultivation. Emergence of radicle and/or plumule were taken as the criteria of successful germination. Seeds were also planted in pots with different types of soils to determine the most favorable soil type for the *ex situ* cultivation experiment.

***Ex situ* experiments:** The Latin square experimental design was applied in the cultivation experiment. It consisted of 4 columns and 4 rows representing geographical areas. Sixty-four pots were used to represent all sites. At the beginning of the experiment watering of seeds was completely dependent on the rainfall, then irrigated once every two days with 500 mL tap water which preliminary have been estimated to represent the water field capacity. Germination percentages and phenological records were taken through the period of the experiments. *Ex situ* experiments were carried out for two successive years: In the first year, cultivation was carried out for seeds collected from their natural sites (wild populations). In the second year, seeds collected from individuals produced in the first year were cultivated. Experiments were carried out in the Botanic garden of the Faculty of Science, Alexandria University.

Measured attributes: Mature individuals of *Polygonum equisetiforme* Sm. were collected to estimate morphological traits. These traits include: Height of the plant; number of branches/individual.; length of branches.; length of internodes; number of leaves/branch; width of leaf; length of leaf; length of ochrea; number of flowers/individual.

Transverse thin hand sections were applied to the sampled specimens of stem, leaf and the main root. Sections were examined under the light microscope to expose different tissues and layers. Measurements, for at least five sections, of the thickness of each tissue were determined by means of the stage micrometer.

Seed morphology was studied using the Scanning Electron Microscope (SEM). Seed weight (mg), width and length (mm) of 50 dry seeds representing each site were measured and the average seed weight at each site was calculated. Total seed protein was determined according to the method described by Hartree (1972).

Analysis of data: TWINSPAN was applied for the morphological attributes to evaluate the consistency, or not, of the indicator character between the groups of plants representing the wild populations and those representing successive progenies. Indicator character(s) refers to the most influencing character(s) that sort certain populations' sites in a specific cluster at a certain level of similarity (CAP, 2002). The complete linkage method of Euclidean distance (Statistica 5.0, 1995) was applied for seed and anatomical attributes.

RESULTS

The soil samples representing sites of the western province of the western section are generally characterized by low content of organic matter, low salinity and high content of calcium carbonate in contrast to those of the Nile Delta section which are characterized by high level of organic matter, high salinity and low calcium carbonate content (Table 1).

Table 1: The sampling sites, their given symbols and average (Mean±SD) measured soil characteristics of the wild plant population of *Polygonum equisetiforme*

Geographical regions	Symbol	Sites	EC (mmohs)	OM (%)	pH	$CaCO_3$ (%)	Texture (%) Clay	Silt	Sand
The western province of the western section (WP)	WP1	El-Qasr	0.27±0.03	2.50±0.18	8.50±0.04	52.95±1.26	3	1	96
	WP2	Mersa Matruh	0.23±0.02	2.56±0.10	8.45±0.04	71.50±1.21	2	1	97
	WP3	Ras El-Hekma	0.23±0.01	2.56±0.07	8.44±0.02	57.11±0.80	6	2	92
	WP4	Dabaa	0.20±0.01	2.40±0.05	8.49±0.03	15.90±0.35	3	1	96
	WP5	Alamein	0.22±0.02	2.04±0.06	8.48±0.02	29.70±0.53	3	4	93
The eastern province of the western section (EP)	EP1	Omayed	0.79±0.02	3.36±0.07	8.28±0.03	49.38±0.26	4	4	92
	EP2	El-Hammam	0.58±0.02	2.30±0.02	8.33±0.03	21.93±0.28	4	3	93
	EP3	Burg El-Arab	0.73±0.02	2.56±0.04	8.77±0.02	17.02±0.14	2	1	97
	EP4	Maamoura	0.71±0.03	3.14±0.03	8.56±0.02	16.43±0.24	3	3	94
	EP5	Abu Qir	0.52±0.03	3.36±0.03	8.33±0.03	17.73±0.10	4	3	93
	EP6	Abies	0.70±0.02	2.30±0.03	8.20±0.02	36.35±0.78	2	1	97
	EP7	Tabia	0.72±0.02	3.89±0.03	8.01±0.01	14.83±0.19	2	3	95
	EP8	Khorshid	0.60±0.03	3.18±0.02	8.30±0.03	10.09±0.13	3	2	95
Nile Delta section (ND)	ND1	El-Bousseli	1.31±0.04	4.17±0.03	8.16±0.02	7.89±0.13	5	5	90
	ND2	Edfina	0.45±0.02	3.09±0.02	8.00±0.03	7.42±0.06	3	1	96
	ND3	Rosetta	0.19±0.01	8.25±0.01	8.11±0.03	3.85±0.08	8	8	84
	ND4	Damanhour	0.35±0.02	6.73±0.02	8.09±0.03	6.53±0.06	4	4	92
	ND5	Tanta	0.44±0.02	3.03±0.03	8.01±0.02	5.28±0.06	3	4	93
	ND6	Mansora	0.78±0.03	9.89±0.03	8.05±0.03	15.20±0.05	8	7	85
	ND7	Damietta	1.83±0.05	2.04±0.01	8.09±0.03	4.85±0.07	2	1	97
	ND8	Ras El-Bar	0.75±0.01	5.92±0.03	8.10±0.01	4.75±0.04	3	8	89
North Sinai site	NS1	El-Arish	0.61±0.03	4.00±0.26	8.20±0.02	5.80±0.07	2	10	88

Germination experiments showed that seeds of *Polygonum equisetiforme* Sm. require a storage period before starting to germinate for most sites, while further variability in germination percentages did occur with extending the storage period of seeds. The storage period for active germination exceeded two months for seeds representing most of the sites (Fig. 1a). However, although the germination percentages increased gradually along with increasing the period of storage from three to nine months, yet, in general, lower germination percentages were attained under 30±2°C regime. The experiment conducted to determine the most appropriate soil type for seed germination showed that sand loam is the best choice, which is supported by the high germination percentages obtained in most of the cases. These percentages reached 60.0, 73.3, 60.0 and 26.7% for the plant populations of the western section (EP andWP), Nile Delta and north Sinai sections respectively (Fig. 1b).

The number of germinated seeds reached its maximum after three months. The maximum number (134) was recorded for the seed populations collected from the Nile Delta section during the first progeny while the minimum number (25) was recorded for those collected from north Sinai (Fig. 2). Plants reached their peak of flowering and fruiting after five months. The total number of established individuals was smaller in the second progeny than that recorded in the first year.

Dense and the largest leaf dimensions characterize wild individuals of Nile Delta section while, the lowest number and the smallest leaves were recorded for the wild individuals of the western province (Fig. 3). The number of leaves per branch, in most sites, decreased in the cultivated progenies. Notable differences in the obtained values of the number of leaves and leaf dimensions were found for the individuals produced in the first progeny for all sampled geographical areas. These differences seemed to diminish in the individuals produced in the second progeny.

The number of flowers per individual varied greatly from wild individuals to those grown *ex situ* (Fig. 4). A maximum of 151/individual produced by wild populations of the Nile Delta section. This number greatly dropped in the first and second progenies (25 and 16 flowers/individual, respectively).

The anatomical features of the stem appear to be similar in all populations. The ratio between different layers' thickness for stems with primary structures of specimens collected from natural habitats and those

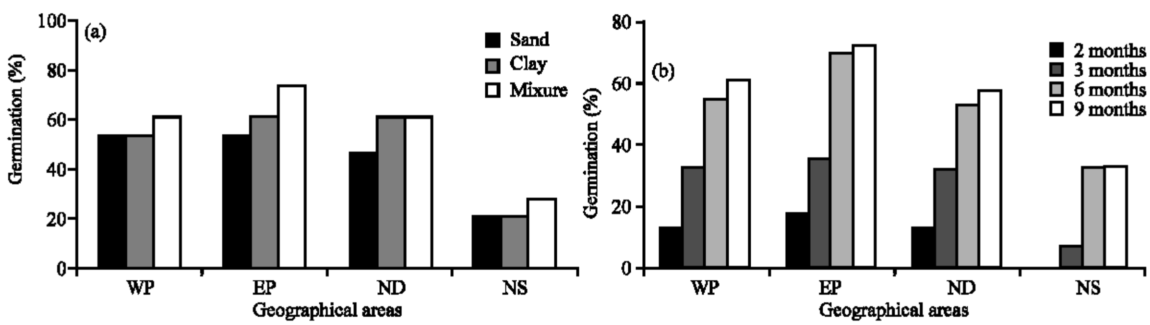

Fig. 1: Germination % in different soil types (a) and different storage periods (b) of he wild populations of *Polygonum equisetiforme* for the sampled geographical areas

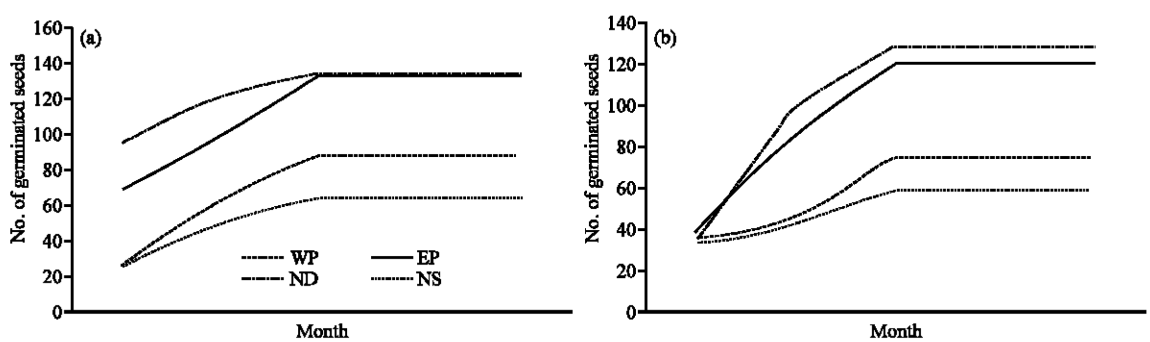

Fig. 2: Variations in the number of established individuals (out of 320 seeds in 16 pots representing each sampled geographical are) at different time intervals in the first progeny (a) and the second progeny (b)

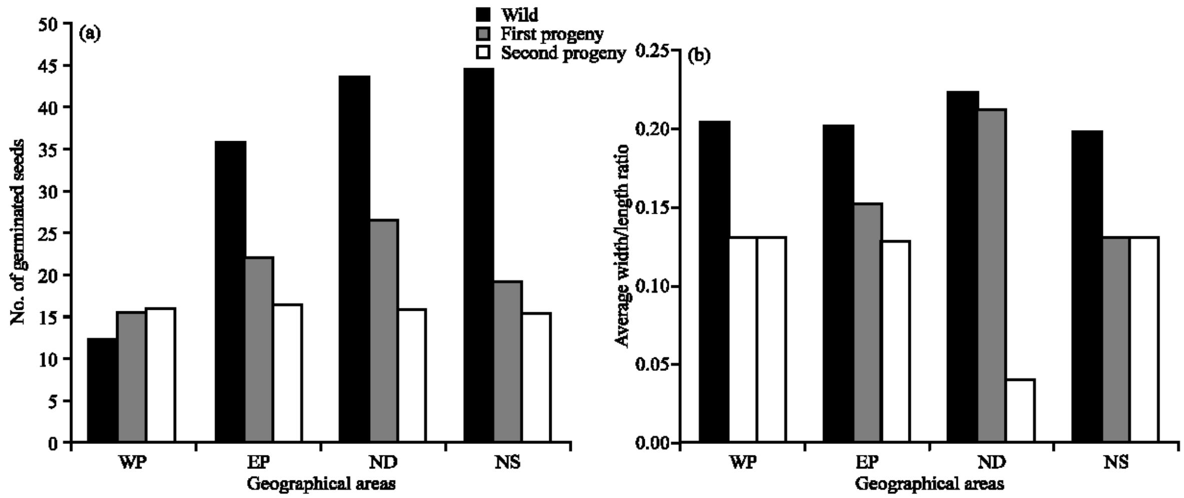

Fig. 3: Average (mean±SD) numbers leaves (a) and widths/lengths ratios (b) of the wild and cultivated individuals of *Polygonum equisetiforme* for the sampled geographical areas

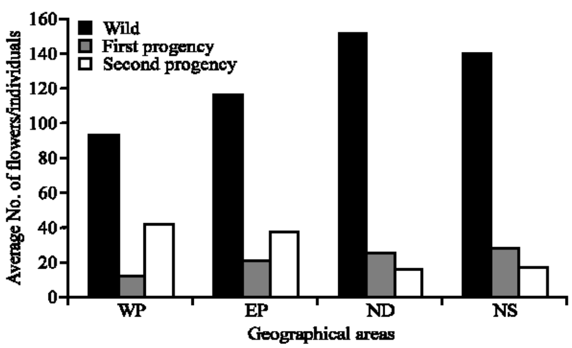

Fig. 4: Average (mean±SD) number of flowers/individual of the wild and cultivated individuals of Polygonum equisetiforme for the sampled geographical areas

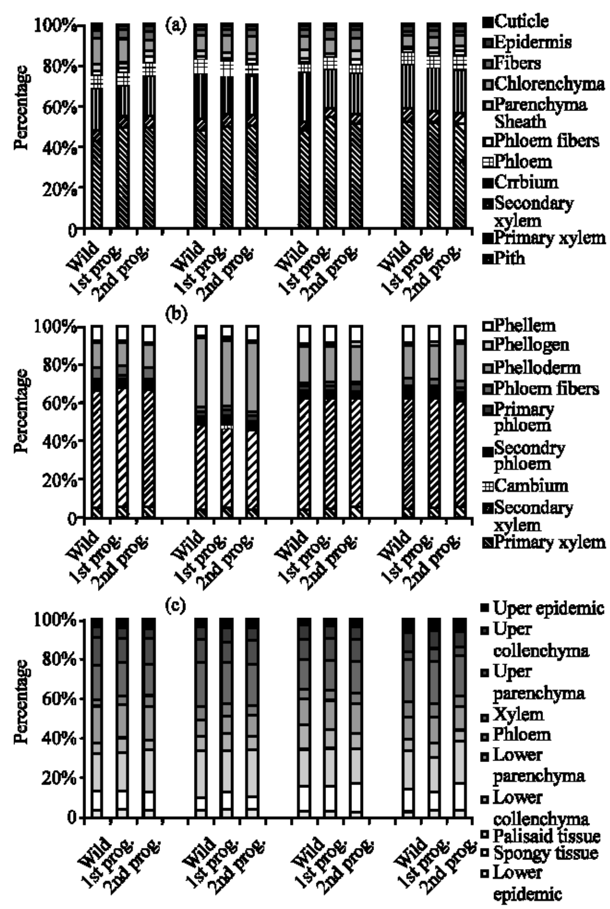

Fig. 5: Stalk histogram shows layers thickness percentages in the stem (a), root (b) and leaf (c) of the wild and cultivated specimens of polygonum equisetiforme representing the sampled geographical areas

grown *ex situ* is presented by stalked histograms in Fig. 5. Investigated specimens for stems with secondary activity showed no great difference in tissue characteristics as well as the arrangement of layers.

Seed specimens of the studied species are small and trigonous, dark brown and characterized by a broad end at one side and a narrow one at the other side (Fig. 6). The seeds produced from the cultivated progenies tend to be lighter and have shorter and broader body compared to those of the wild populations. The ratio of seed width to length in the present study reflects the shape. It ranges from a minimum average of 0.56 for specimens' populations of the western province produced from the second year progeny to a maximum average of 0.73 for the wild specimens' populations of north Sinai section (Fig. 7).

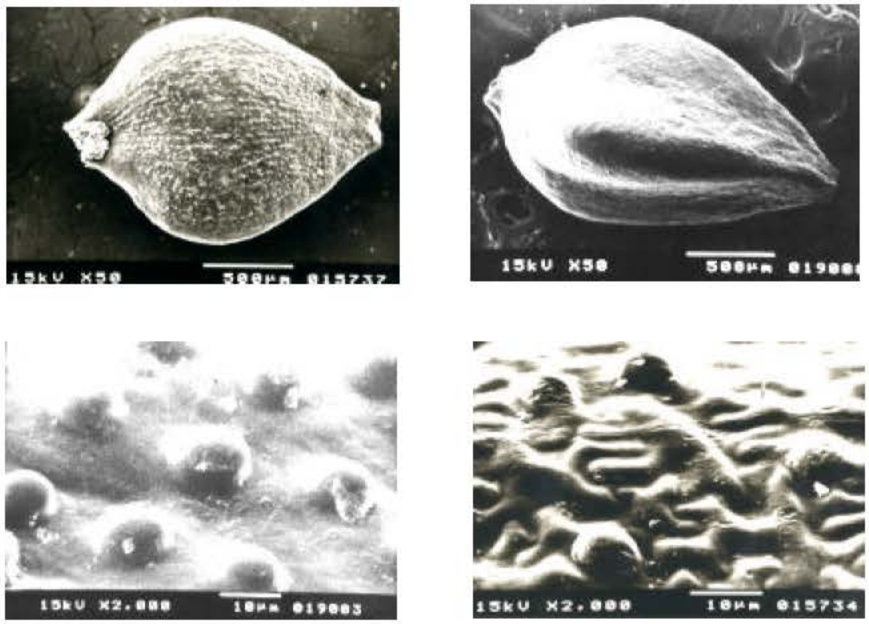

Fig. 6: Variations in seed shape (X50) and seed coat ornamentation pattern (X1000) of the wild and cultivated plant individuals of *Ploygonum equisetiforme* as shown by the Scanning Electron Microscope

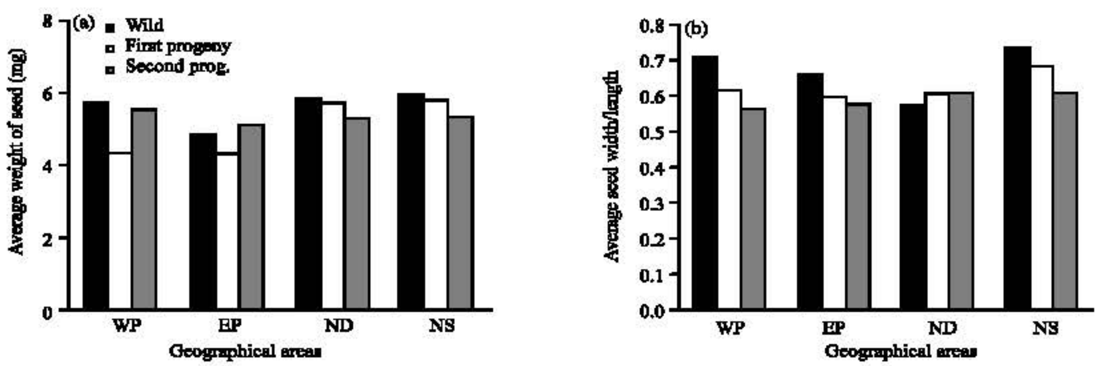

Fig. 7: Comparison between the average (mean±SD) weight (mg) of seeds (a) and width to length ratios (b) in the wild and cultivated individuals of *Polygonum equisetiforme* for the sampled geographical area

Concerning the texture of the seed coat, on the one hand, seeds of wild populations of both the eastern province of the western section and Nile Delta section showed wavy ornamentation pattern. On the other hand, seed coat of the wild individuals of the western province of the western section and north Sinai section showed very shallow papillae ornamentation (Fig. 6). This pattern appeared clearer and sharper in the individuals produced from the first progeny. Meanwhile, a shallow wavy ornamentation was the main feature to the seed coats of all sampled of the second progeny.

Application of cluster analysis based on morphological attributes classify the 22 populations' sites of *Polygonum equisetiforme* Sm. into groups at different levels of similarities. Wild populations' sites of the western province are grouped in one cluster at the

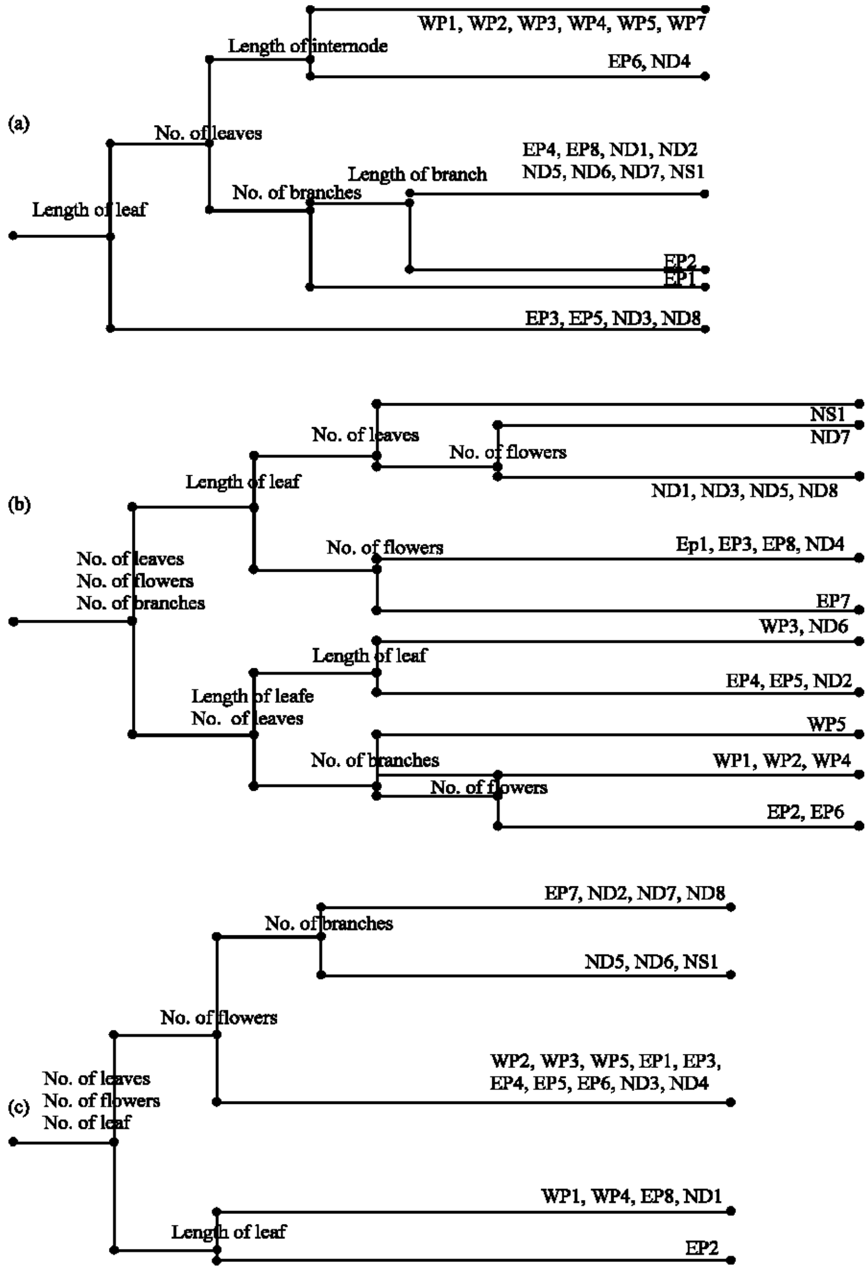

Fig. 8: Hierarchial classification of the 22 populations' sites of *Polygonum equisetiforme* based on the morphological attributes using TWINSPAN technique (a) wild populations' sites (b) populations of the first progeny and (c) populations of the secondary progeny

third level of dissimilarity where the length of internodes is the main indicator character. Most sites of Nile Delta section are distinguished in one cluster at the fourth level and the length of branch is the indicator character (Fig. 8). Groups resulted by the application of TWINSPAN technique did not explain clearly whether the resulted groups of *P. equisetiforme* based on anatomical measures and seed attributes are environmentally affected or they are genetically controlled. Consequently, the Euclidean distance coefficient for data set was applied. Classification of seed attributes revealing that seed attributes were largely affected by the environmental changes (Fig. 9).

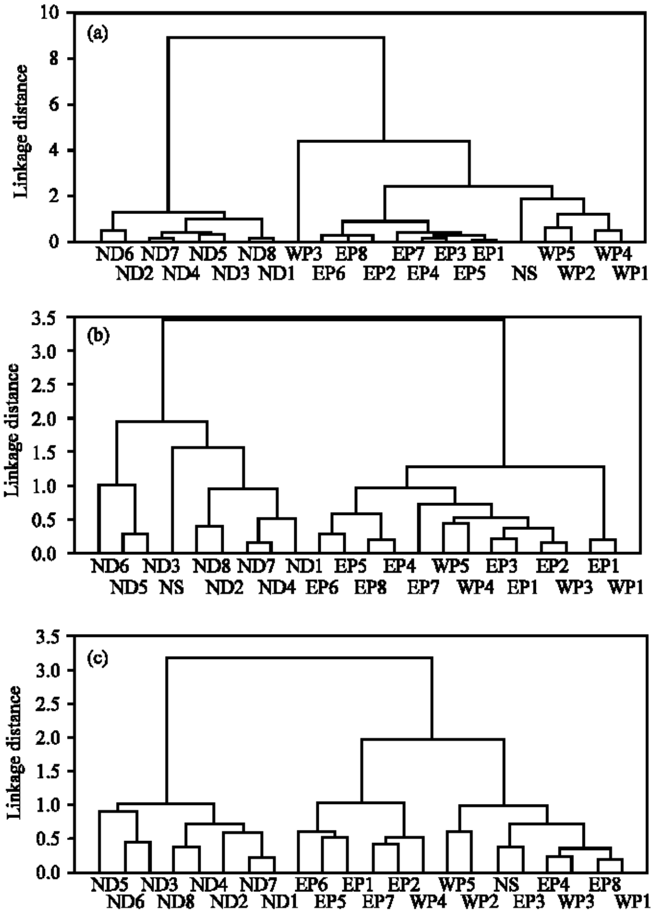

Fig. 9: Cluster analyses based on the measured seed attributes of *Polygonum equisetiforme* in the sampled geographical areas according to complete linkage euclidean (a) tree diagram of wild population (b) tree diagram of the first progeny and (c) tree diagram of the second progeny

DISCUSSION

Field observations showed that *P. equisetiforme* Sm. grows in a broad environmental range. Thus, the study species may be an ecological generalist; with individuals able to maintain fitness in a wide range of environments as suggested by Sultan (2001). The present study illustrated that wild individuals collected from Nile Delta and North Sinai sections, with relatively favorable resources-rich conditions, exhibited larger sized individuals with vigorous growth compared to those of the western section, which could reflect fitness capacity. Highest growth performance of the wild population of Nile Delta section may also be attributed to the embedded properties of the soil texture of this section, which contains higher clay percentage than other sections and much more soil available water and nutrients. On the contrary, the western section is characterized by low contents of Ca and Mg and high content of fine sand (Tadros and Rezk, 1969). low organic matter, high salinity and high $CaCO_3$ % were also recorded for this province in the present study. Therefore, it may not represent a suitable habitat for the distribution of *P. equisetiforme*.

In plants, offspring size and quality affect germination, emergence and seedling growth rates and consequently survival, establishment and fecundity of the offspring generation (Lloret *et al*., 1999). *Ex situ* progenies of the Nile Delta section exhibited the highest percentage of survived individuals, which may reflect a distinguished fitness of this population than those produced from other sections. Galloway (2001) proved that parental environments may influence life history evolution of *Campanula americana* and the expression of traits in its offspring.

The present study demonstrated that the timing for flowering and seed production is almost a month earlier for the *ex situ* experiments compared to those produced in nature. This may reflect a plastic response in the timing of reproduction (one of the fitness components), since plant in nature encounter numerous interacting stresses. Reproductive output also reveals a plastic response to ensure faster reproduction and complete life history in the new environment. Grime *et al.* (1986) suggested that differences in the plastic responses of flowering time should occur between plants from contrasting habitats. They proposed that in unfavorable environments, plants from disturbed habitats are expected to reproduce earlier than plants from competitive habitats to ensure reproduction. Contrary to these predictions, Dorken and Barrett (2004) found that plants from disturbed habitats had delayed flowering when grown in low resource conditions, while those from competitive habitats either had accelerated flowering time or did not flower.

The wild populations of Nile Delta section exhibited the highest number of flowers production. This may reveal to the direct relation between soil organic matter and flower production of *Polygonum equisetiforme*. Sultan (2001) proved that *Polygonum* species increased their reproductive output when they were grown in resource rich conditions. *Ex situ* cultivations showed a reduction in the number of the flowers produced in the two progenies relative to that in the wild. This could be attributed to the natural habitats of the wild populations of *P. equisetiforme*, which may exert some stresses from the surrounding environments, consequently; these plants tend to produce more flowers as an attempt to maintain their existence and to ensure the reproduction under unpredictable conditions. In general, it could be stated that the reproductive outputs resulted from the *ex situ* experiments were lighter, smaller and fewer in number compared to those collected from their natural habitats. Variability in the seed weight of *P. equisetiforme* in the present study may agree with the idea stated by Sultan (2000) who reported that plants might respond to environmental conditions not only by adjusting their own phenotypes but also by altering their offspring through changes in the quantity and quality of seed provisioning. This can be attributed to the presence of different stresses that *P. equisetiforme* may encounter in its natural habitats to complete its life. Harper (1977) proved that plants commonly increase the number of reproductive structures while keeping their sizes relatively constant in response to increased resources. The changes in seed size and mass in the present study support the notion that these characters may be environmentally induced rather than genetically fixed characters.

The variation of leaves number and dimensions in individuals of the first progeny would suggest a step towards adaptation to the new environment. Meanwhile, the state of stability performed by plant individuals of the second progeny may reflect the output of adaptation to this new environment, which indicates a high plastic attitude of the leaf traits in *P. equisetiforme*. There is a plastic response in the leaf traits of the Nile Delta section to increased resource availability. Variability in leaf size affects the ability of plants to capture light and therefore compete with neighbors (Belaguer *et al.*, 2001). It may be concluded that variability in leaf traits seems to be an environmentally affected character.

Plants from relatively stable or predictable environment are expected to make more or less fast switch-over from vegetative to reproductive phase of growth in order to optimize seed production (Cohen, 1976). In the present study flower production of wild populations was delayed than the cultivated progenies, however, it may then switch-over, rapidly and with higher extent to reproductive growth on the expense of vegetative growth. On the contrary, *ex situ* populations exhibited a tendency for vegetative growth on the expense of producing seeds. Moreover, plant individuals allocate its energy for more vegetative rather than seed reserve. The above findings are in agreement with many authors (Pigliucci, 1997; Sultan, 2001; Dorken and Barrett, 2004; Galloway, 2005).

Studies of anatomical plasticity shed further light on the subtle ways that plants might adjust their phenotypes to maintain function in different conditions (Cordell *et al.*, 1998). Plants might respond to their environments through developmental plasticity in many aspects of their phenotypes and the anatomical traits might vary with the environment (Fernandez-Lopez *et al.*, 1998). Measurements of thickness of layers representing different functional tissues (protective, supporting and conductive) were found to be characteristic to different geographical areas. Wild and cultivated progenies of the western province showed tendency of their individuals to contain the highest amount of protective tissues in their leaves; supporting tissues in their stems and conductive tissues in their roots. This probably reflects the great response of this population to environmental conditions. However, fluctuation in the thickness of these tissues in the cultivated progenies leads to the assumption that thickness of layer is an environmentally affected character. However, arrangement of layers in *Polygonum equisetiforme* is mostly genetically fixed as they exhibited the least change affected by the environmental changes.

Some attributes of the studied species may reveal a clue to follow the allocation of resources which serve the plant growth in its natural habitat and in *ex situ* cultivation. In the western province, there is a notable decrease in thickness of assimilating tissue in the stem, from the wild individuals to the cultivated progenies. This reduction was accompanied by an increase in the thickness of palisade tissue of leaves. At the same time, there is a notable increase in plant height, branch length, number and leaf dimensions. This was also associated with a notable decrease in the number of the flowers and seed weight from the wild individuals to cultivated progenies. Thus, the allocation of resources seems to serve vegetative growth rather than reproductive growth which would indicate a form of phenotypic plasticity in the studied species.

Remarkable reduction in the flower number of *ex situ* cultivations (83 and 78%, respectively) than those of the wild may also refer to the effectiveness of this character as a key indicator. Sultan (2000) paid attention to the aspect of plasticity that is related directly to the functional and reproductive success of plants in their environments. The present study showed that the number of flowers produced by the studied species has an effective role on distinguishing populations' sites. This role was obscured in the original wild habitats but its role as an effective character was obvious in the two successive *ex situ* progenies.

Seeds of *P. equisetiforme* of the present study have two forms of ornamentation pattern (wavy and papillae). However, sampled seed' showed that wavy ornamentation pattern of seed coat is more frequent in than the papillate form. In this respect, Bidak (1993) proved that seed coat structure and shape did not exhibit any variations that can be linked to the geographical location, habitat type or even the soil type and she concluded that these characters are consistent and genetically fixed.

The protein content of the seeds in the present study is directly proportional to the weight of seeds. Previous researchers proved the absence of association between protein content and seed weight (Lafiandra *et al*., 1981; Dixit *et al*., 1995; Gatta *et al*., 2006). The diverse relation between seed weight and protein contents in the wild populations and first progeny in one hand and these two traits in the second progeny, on the other hand may support the conclusion evidenced by Granati *et al*. (2003) who stated that both traits are under independent genetic control.

Electrophoresis separation of protein bands in the sampled of *Polygonum equisetiforme* showed that all samples has the same protein bands. Four clear bands at molecular weights of 250, 95, 64 and 36 kDa were observed in all the studied samples. This may reflect the consistency of the same kinds of protein and suggests the absence of genetic variation within different individuals collected from different geographical areas. It also reveals that the protein pattern of the study species tends to be genetically fixed character rather than affected by environment.

Variation of seed dimension and weight provide evidence of both habitat and geographical location effects. Wild population of Nile Delta section proved to contain the lowest seed reserve of protein content compared to other geographical areas. The persistence of all sites representing this section in a definite group in the resulted dendrograms of wild populations and cultivated progenies support the idea that the populations of this section are more or less habitat related. This supports the notion that seed reserve and shape are environmentally induced rather than being genetically fixed characters. Results also suggest the low genetic variation among populations of *P. equisetiforme* representing different sites.

The analysis of the results and extracted interpretations answered to an acceptable extent the questions raised at the introduction. Regarding the first one declared; which plant populations show more plasticity in response to various environmental conditions? the present study proposes the population of Nile Delta section to be considered as exposing the best plastic responses to different conditions. However, this section is exposed to further stress relative to the other sections, as most of the selected sites were located nearby the roadways, fallow fields and wastelands affected by agriculture practice activities and constructions.

On the answer of the second question stated; how do plants from different geographical areas respond to different environmental conditions?, it is noted that while the length measures of different organs for the wild populations dominated the ranking (60%), it was the number measure of attributes that dominated the ranking for the first and second progenies (80 and 67%). This would imply a shift from enlargement to intensity then a balance in growth factors in response to environment. Indeed, it could be asserted that *P. equisetiforme* in natural environment tends to increase the lengths of organs, trying to maintain itself and faces the different stressed environments.

For the third question; how fast do plants from different habitats reach reproductive maturity when cultivated? the flowering and seed production are almost a month earlier for the *ex situ* experiments compared to those produced in nature. This may reflect a plastic response in the timing of reproduction. Furthermore, while the wild individuals produce a larger number of flowers to come across natural interacting stresses for species survival, the reproductive output in *ex situ* experiments reveals a plastic response to ensure faster reproduction and complete life history with least energy cost taking the advantage of more or less a stable new environment.

As for the fourth question; do materials raised from *ex situ* seed typically resemble wild plants of the habitats samples?, the seed protein content of *P. equisetiforme* produced from the *ex-situ* experiment showed notable decrease compared to those of wild populations; a type of plasticity of this trait. The protein content of the seeds was directly proportional to the weight of seeds in both the wild populations and successive progenies in case of Nile Delta and North Sinai sections; this result is reversed in the second progeny of the western section. This may also, reflect plasticity in these two characters.

With respect to the fifth question; how do local adaptation and individual tolerance contribute to the distribution and abundance of the study species; The variability in the geographical distribution of *Polygonum equisetiforme* could reflect the varied capacities of its populations to maintain performance and reproductive fitness under diverse environmental conditions. This species may be considered as an ecological generalist as its individuals are able to maintain fitness in a wide range of environments. The vigorous growth and successful competition with other species in some of these habitats propose a tolerance aspect of the species.

For the last question, the present study suggests that plasticity in *P. equisetiforme* is a character specific attribute; the following characters showed plasticity:

1: Time of reproduction, the flowering and seed production are almost a month earlier for the *ex situ* experiments compared to those produced in nature;
2: Tendency of wild populations to produce higher number of flowers and heavier seeds and more seed reserve of protein;
3: Variations in the number and dimensions of leaf traits and
4: Fluctuation in the thickness of protective, supportive and conductive tissues.

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