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Modeling the Growth of *Malva parviflora* Growing in Two Different Bioclimatic Regions

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Abstract: A random sample of 526 individual plants *of Malva parviflora* growing in two different bioclimatic regions were collected to examine the effects of different environmental conditions present at different bioclimatic regions on the growth patterns of this medicinally important plant using Richard's, Von Bertalanfi's and Gompertz growth models. Model parameters were calculated using plant height, leaf length, petiole length and leaf weight as the growth determining parameters. There were differences in the growth patterns of plants growing in the warm bioclimatic region when compared with plants growing in the cool bioclimatic region. These differences indicated that different environmental conditions present at different bioclimatic regions can affect the growth of *Malva parviflora*. Plants growing in warm regions had a longer growth period and a higher maximum plant height and petiole length and those growing in the cool region had a higher petiole length and leaf weight.

Key words: Bioclimatic regions, growth models, *Malva parviflora*, growth parameters

INTRODUCTION

Malva parviflora is used in Jordan and in other countries as a medicinal plant. It is used as a demulcent for the treatment of coughs and ulcers in the bladder and as a poultice on swellings, running sores and boils (Saad *et al*., 1988). *Malva parviflora* in Jordan grows in two different bioclimatic regions (biogeographical regions) which vary in the mean maximum temperature and the mean annual rainfall. There are considerable reports in the literature that indicate that environmental factors have effects on morphology and architecture of plants that include changes in size, structure and spatial positioning of plant organs (Huber *et al*., 1999). These changes result from environmentally induced changes in the growth and allometry of a number of plant structures such as petiole length, internode length and meristem outgrowth (Bonser and Aarssen, 2001). Although limited in number, there are studies that examined the effects of environmental factors on the growth and allometry of plants.

Kume and Ino (2000) investigated the effects of a heavy and light snowfall habitats on the shoot size and allometry of two evergreen broad-leaved shrubs. They showed that the size of new shoots and leaves were significantly different between the two varieties with different critical shoot sizes for flowering. Stamp *et al.* (2004) studied the effect of competition on plant allometry and defense. They found that there was a change towards less root mass for greater height as competition increased while competition did not affect leaf proteinase inhibitor activity or petiole glandular trichomes or total trichomes. Schenk and Jackson (2002) studied the effect of water limited environments on the rooting depth, lateral root spreads and below-ground/above-ground allometries of plants. They reported that root system sizes differed among growth forms and increased with above-ground size starting from annuals which represent the minimum and ending with trees that represent the maximum. Sack *et al.* (2003) studied the effects of combined shade and drought on the morphology of plants. They reported that contrary to what has been hypothesized that plants can not tolerate combined shade and drought, the studied plant species showed tolerance to both shade and drought by reducing demand for resources. Henry and Thomas (2002) examined the effects of lateral shade and wind on the stem allometry while Huber and Stuefer (1997) studied the shade-induced changes in branching pattern. Both reported that shading can lead to modifications in plant stem height, growth form and architecture. A number of studies modeled either the influence of stress and stimulus factors from air and soil on plant growth (Chen *et al*., 1998), the interacting effects of browsing and shading on mountain forest tree regeneration (Weisberg *et al*., 2005) or the optimal root-shoot allocation and water transport in clonal plants (Stuefer *et al*., 1998).

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The purpose of this research is to model the growth of *Malva parviflora* growing in two different bioclimatic regions by calculating the growth parameters of this plant using three growth models to determine if there are effects caused by the different environmental factors present at these two bioclimatic regions on the growth of this plant.

MATERIALS AND METHODS

Study sites and species: Based on rain distribution during the year, Jordan is considered to be of Mediterranean bioclimatic region since rainfall is mainly in winter and spring. The two studied bioclimatic regions; Mafraq which is of Arid Mediterranean bioclimate of cool variety with mean annual rainfall of 164.0 mm. It is characterized by mean maximum temperature of 32.3°C in August as hottest month and mean minimum temperature 1.8°C in January as the coldest month. The second site, Zarqa is of Arid Mediterranean bioclimate of warm variety and mean annual rainfall of 148.0 mm. The mean maximum temperature is 33.2°C in August and the mean minimum temperature is 3°C in the coldest month (January).

The two regions are characterized by warm summer, which is definitely warmer in arid zone than in cool zone (Al-Eisawi, 1996).

Depending on bioclimatic and vegetation characteristic, vegetation in the Middle East is of four regions; Mediterranean, Irano-Turanan, Saharo-Arabian and Sudanian (Zohary, 1973). The two studied areas are considered to be of Irano-Turanain vegetation (steppe region). which is characterized by poor eroded soil and calcareous or loess type (transported by wind). The vegetation is a timber less land (no trees) with mostly shrubs and bushes.

Malva parviflora L. is an annual, hairy herb with erect to prostrate stem. The leaves are petiolate, orbicular in outline, cordate to reniform at base and crenate. Flowers range from 2-4 or more in axillary clusters, with a pink to purple color, sometimes white. Fruits are glabrous rarely hairy and prominently wrinkled (Zohary, 1972). The growing season of this plant is between the months of January and May.

Sampling and analysis: A sample of 526 healthy plant individuals (whole plant with its complete root system) was randomly collected from an area of 0.5 km^2 from the two sites during the growing season from January to May. Collected samples were immediately placed in plastic bags and sprinkled with water and returned to the laboratory within two hours. The root of plants was submerged in water for 16-20 h. One leaf (youngest fully expanded) was harvested from each plant by cutting the petiole at point where it is completely separated from the main axis. Petioles were excised from leaf blade and length of each was recorded. The measured leaves and petioles were dried at 70°C to constant weight and the weight of each was determined.

For each individual plant the plant height (PH), stem width (SW)), petiole length (PL), leaf length (LL), leaf width (LW), root length (RL), leaf dry weight (LDW) and petiole dry weight (PDW) were measured (Nagashima and Terashima (1995), Verwijst and Wen (1996) and Chang *et al.* (2004).

Modeling and statistical analysis: Plant height was used to represent plant growth. Leaf width, petiole length and petiole dry weight were also used in growth modeling of *Malva parviflora*. The collected plants were divided into size groups of plant height intervals calculated using histogram plots that show normal distribution of plant height. This calculation was carried out using computer based statistical software (STATISTICA software for windows. StatSoft, Inc., Tulsa, OK, USA) to compute the number of possible cohort sizes that best fits the normal distribution (Ismail and Elkarmi, 1999). Plant height was theoretically calculated using Richard's: $H_t = H\infty [1\text{-}A*e^{-kt}]$ and Von Bertalanffy growth models: $H_t = H\infty [1\text{-}e^{-k(t - t0)}]$ (Ismail and Elkarmi, 2000) and Gompertz growth model (Aiba and Kohyama, 1996; Elkarmi, 1998): $Ht = H\infty [e^{(-A*e(-kt))}]$, where H_t is the plant height at age t, $H\infty$ is the plant height at age ∞, A is the growth model constant, k is the growth coefficient and t_0 is the age at which the length is theoretically nil. The constants $H\infty$, k and t_0 were calculated using the quasi-Newton method (Ostle and Mensing, 1975). The same models were also applied to petiole length Leaf width and petiole weight. These growth models were applied to plants growing at both bioclimatic regions.

RESULTS

Based on the assumption that plant height is normally distributed (Ismail and Elkarmi, 1999) the results indicate that the plants growing in the warm bioclimatic region have a growth period of five months while plants growing in the cool bioclimatic region have a growth period of four months (Fig. 1).

All three growth models successfully calculated the growth parameters of *Malva parviflora* growing in both the warm and the cool bioclimatic regions (Table 1; Fig. 2 and 3). For example the growth parameters

Table 1: Results of the Richard's, Von Bertalanfi's and Gompertz growth models

	Richard		Von Bertalanfi		Gompertz	
	Cool region	Warm region	Cool region	Warm region	Cool region	Warm region
Plant height (mm)						
H∞	520.221	871.8	580.635	871.823	517.53	546.876
A	1.1	1.08	0.88	0.784	1.8	1.7
k	0.35	0.1	0.4	0.1	0.41	0.14
r	0.932	0.996	0.992	0.996	0.872	0.781
Leaf length (mm)						
LL∞	67.677	145.481	88.408	145.48	70.625	97.846
A	0.95	1.038	0.538	0.185	1.75	0.95
k	0.51	0.2	0.47	0.2	0.65	0.25
r	0.888	0.97	0.991	0.97	0.912	0.773
Petiole length (mm)						
PL∞	236.629	197.189	286.182	197.189	209.105	152.824
A	1.2	1.088	0.762	0.425	1.9	1.05
k	0.4	0.2	0.34	0.2	0.55	0.15
r	0.965	0.983	0.993	0.983	0.899	0.713
Leaf weight (mg)						
LW∞	164.313	146.852	153.681	114.997	149.401	55.370
A	1.338	1.1	0.971	0.2	1.99	0.99
k	0.3	0.1	0.33	0.1	0.32	0.1
r	0.767	0.966	0.760	0.92	0.7	0.520

H∞: Plant height at age ∞ (maximum height), LL∞: Leaf length at age ∞ (maximum leaf length), PL∞: Petiole length at age ∞ (maximum petiole length), LW∞: Leaf weight at age ∞ (maximum leaf weight), k: Growth coefficient, r: Correlation coefficient, A: Growth model constant

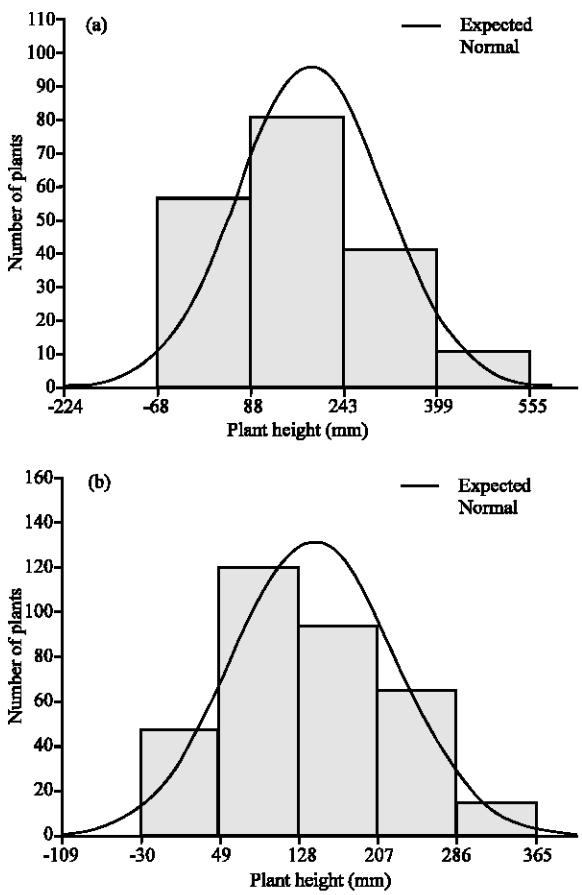

Fig. 1: Frequency distribution according to plant height of estimated length groups showing expected normal distribution for plants growing in (a) cool bioclimatic region and (b) warm bioclimatic region

calculated for plant height (PH) using Richards, Von Bertalanfi's and Gompertz models in the warm bioclimatic region are:

$$PH = 871.8 *(1- 1.08*e^{-0.1*t})$$
$$PH = 871.823*(1-e^{-0.1*(t-0.784)})$$
$$PH = 546.876*[e^{(-1.7*e(-0.14*t))}]$$

For the cool bioclimatic region the models predictions are as follows:

$$PH = 520.221*(1- 1.1*e^{-0.35*t})$$
$$PH = 580.635*(1- e^{-0.4*(t-0.88)})$$
$$PH = 517.53*[e^{(-1.8*e(-0.41*t))}]$$

The growth parameters based on the other plant parts can be calculated from the values listed in the tables. The three growth models used in this study show that the maximum plant height and leaf length for plants growing in the warm bioclimatic region is higher than the plants growing in the cool bioclimatic region, while petiole length and leaf weight are higher in the cool bioclimatic region than the warm region. For example, Richards model calculated the maximum plant height and leaf length for *Malva parviflora* growing in the warm region to be 871.8 and 145.481 mm, respectively and in the cool region to be 520.221 and 67.677 mm, respectively.

On the other hand, Richards model calculated the maximum petiole length and leaf weight for plants growing in the warm region to be 197.189 and 146.852 mg, respectively and in the cool region to be 236.629 and 164.313 mg, respectively.

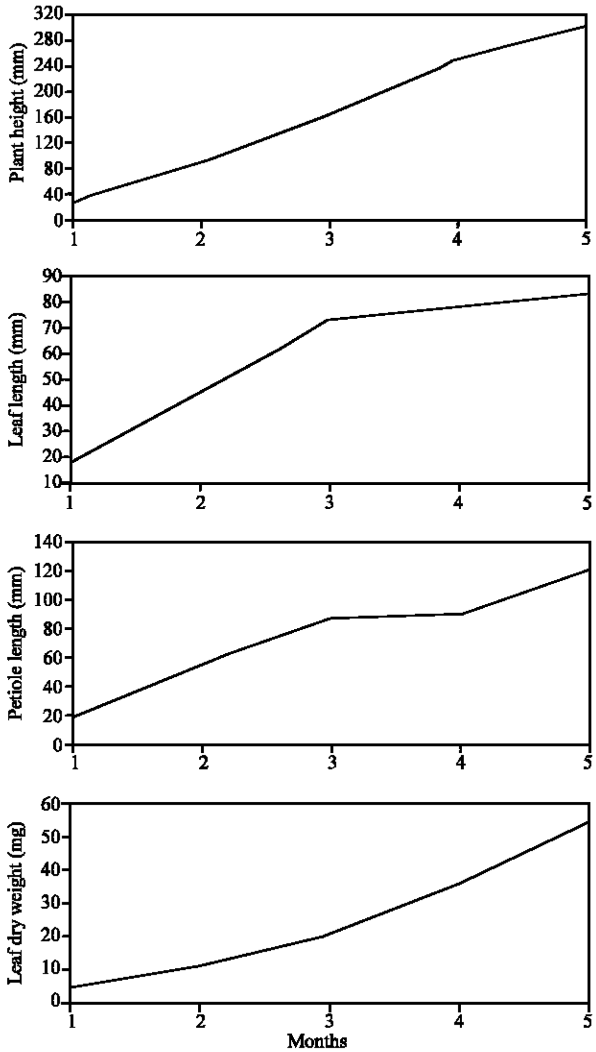

Fig. 2: The relationships between plant height, leaf length, petiole length and leaf weight for plants growing in the warm bioclimatic region according to Richard's growth model

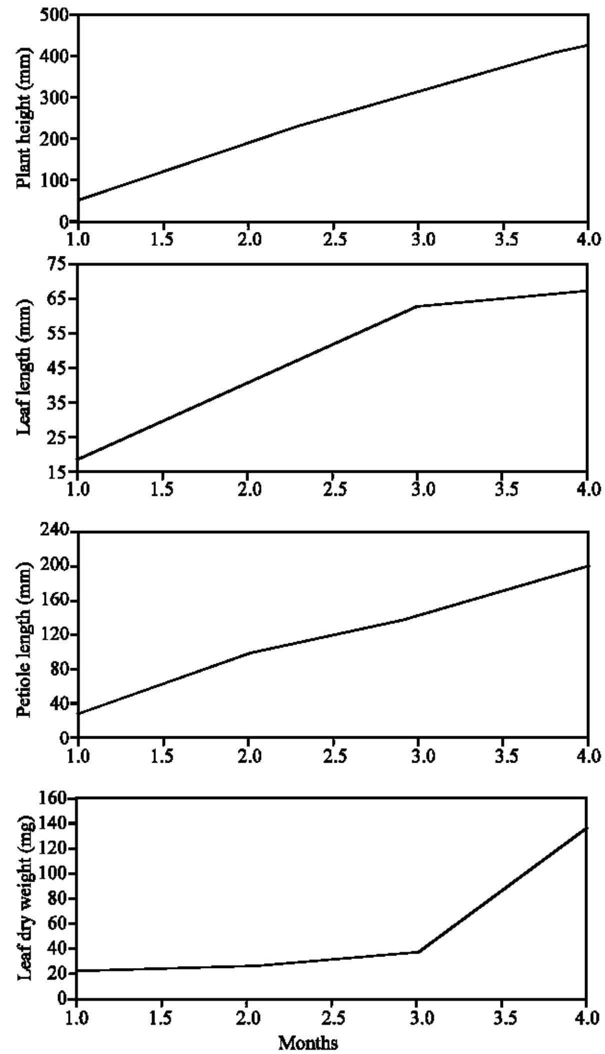

Fig. 3: The relationships between plant height, leaf length, petiole length and leaf weight for plants growing in the cool bioclimatic region according to Richard's growth model

The growth coefficient (k) for all plant parameters is higher in the warm region than in the cool region. For example, Richards model calculated (k) for plant height in the warm region to be 0.1 and in the cool region to be 0.35.

DISCUSSION

The results show a clear difference in the growth of *Malva parviflora* growing in the warm bioclimatic region from those growing in the cool bioclimatic region. It seems that *Malva parviflora* growing in the warm region have a more suitable environmental temperature and thus tend to have a longer growth period and a higher maximum plant height and leaf length. On the other hand, plants growing in the cool region where more rain is expected tend to have higher petiole length and leaf weight.

Although there have been relatively few studies that examined the growth differences between plants growing in different bioclimatic regions, there are few studies that reported the differences in the allometry of these plants and those that show the effects of environmental factors on the growth of plants. Abu Eideh and Elkarmi (2005) reported similar findings to our results when the allometry of *Malva parviflora* was compared between bioclimatic regions. Chang *et al.* (2004) indicated that there are differences in the growth of two herbs one growing in the middle to northern subtropical evergreen forest zones of China and another growing near the banks of creeks and rivers. Shipley and Meziane (2002) reported that growth differences between roots and shoots occur due to variations in irradiance and nutrient supply. Brouat and Mckey (2001) showed that there are differences in growth patterns between myrmecophytes compared to plants with solid stems. Cao and Ohkubo (1998) indicated that less shade-tolerant species tend to have smaller root/shoot rations for saplings taller than 1.5 m. Huber *et al.* (1999) offered a possible explanation for the effects of environmental factors or phenotypic plasticity on the growth patterns of plants. They reported that environmental conditions result in changes in size, structure, spatial positioning of plant organs including internode and petiole length changes, meristem utilization, timing of meristem outgrowth and fate of the meristems. The above mentioned studies indicated that changes in environmental conditions can change the growth patterns of plants and thus are in agreement with our results. In conclusion, there are differences in the growth behavior of *Malva parviflora* growing in two different bioclimatic regions. Plants growing in warm regions had a longer growth period and a higher maximum plant height and petiole length and those growing in the cool region had a higher petiole length and leaf weight.

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