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ORIGINAL ARTICLE

Size-class structure and growth traits of *Anastatica hierochuntica* L. populations as rainfall indicators in aridlands

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Abstract Field data verified by green house experiment were used to evaluate the response of *Anastatica hierochuntica* L. to the amount of rainfall. Field study of the populations was carried out in the runnel and depression microhabitats of gravel and sand sites. Four water treatments, equivalent to 100, 200, 500 and 1000 mm rainfall, were used to simulate different levels of water availability. Under 500 and 1000 mm rainfall, the size-class structure of *A. hierochuntica* populations consists of a high proportion of large size-class individuals, while a higher proportion of small size-class individuals was obtained under 100 and 200 mm rainfall. The dry skeletons of *A. hierochuntica* can be used as a "rain gauge" to predict the amount of rain or water received. The dominance of small size-classes (from <1 to 8 cm^3) gives a prediction of less than 200 mm rainfall received. Intermediate size-classes (8–64 cm^3) characterize habitats with 200–500 mm rainfall, while habitats with >500 mm rainfall produce large size-classes (>64 cm^3). Small size-class individuals produced under low amounts of rainfall allocated up to 60% of their phytomass to the reproductive organs. Allocation to reproductive organs decreased with the increase in the amount of rainfall, while allocation to the stem increased in large size-class individuals produced under the highest amount of rainfall (1000 mm) reaching 54%. Increased allocation to stem in large-sized individuals favours the hygrochastic seed dispersal role in the plant. The root/shoot ratio decreased with the increase of the individual size-class, i.e. under high rainfall treatments. Higher values of relative growth rate, net assimilation rate

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and leaf area index were obtained under high water treatments. Conversely, less expanded leaves, i.e. lower specific leaf area, were manifested in the lowest water treatments.

Introduction

Variation in life history traits is influenced by ecological and evolutionary factors [1]. In desert environments, survival of plant species depends on their adaptive strategies that permit higher reproductive output accompanied by an efficient dispersal mechanism [2,3]. The way in which organisms allocate their energy supplies to vegetative and reproductive structures has been investigated by several authors [1,4–8].

Ecological data support the abundance of annuals rather than that of perennials in disturbed habitats [3,9,10]. Under water stress prevailing in deserts, annuals with short life-spans and greater reproductive allocation (r-strategists) are more favoured than perennials (k-strategists) with long life-spans and smaller reproductive allocation [11,12], especially in unpredictable environments [13]. An annual plant living in a desert environment has to grow rapidly and to convert the energetic and mineral resources obtained during the vegetative phase into seeds [14]. Several studies demonstrated that annuals have higher seedling growth rates [15] and higher allocation to reproductive structures [16]. The early attempt at flowering and the gradual shift of phytomass to reproductive structures may constitute an adaptation to an uncertain environment [17].

Phenotypic diversity and the capacity of a species to adapt its life history traits according to the environmental conditions possibly exist among annual species. A single species exhibits an annual, biennial or perennial life cycle in response to arid unpredictable environmental conditions [8,18]. In this case, the plant may shift from an r- to a k-strategy when a high amount of rainfall is received in wet years and live as an r-strategist in dry years to ensure yearly seed production [8].

Anastatica hierochuntica L. (family: Brassicaceae) is a desert annual, widespread in the Egyptian deserts, characterized by an efficient mechanism of seed dispersal [3,19,20]. This mechanism depends on the hygrochastic nature of the dead curled branches. After senescence, the dry lignified stem branches curl around the enclosed fruits, and then uncurl hygrochastically when wetted by rainfall. Seeds on the uncurled dry plants (skeletons) are released by the force of rain drops on the fruit valves. It is likely that the species may be an effective predictor for water availability in the plant's habitat as rainfall availability and volume are the main limiting factors for seed release and germination. The species is phenotypically plastic in response to the water conditions of the environment [5,21]. The species is subject to over collection for medicinal uses since the infusion of the skeletons was reported to reduce pain and facilitate childbirth and is used as an emmenagogue and for epilepsy [22]. The present work aims at undertaking field and experimental study to investigate the relationship between the amount of rainfall and the crown volume of *A. hierochuntica* skeletons and the possible use of the species as a ‘‘rain gauge’’; and the plasticity of life history traits as affected by the amount of rainfall.

Material and methods

Field data

The populations of *A. hierochuntica* are associated with habitats collecting runoff water such as runnels and depressions. Depression microhabitats accumulate greater amounts of runoff water producing richer growth of the species. Even in desert environments with as low an annual rainfall as 80 mm or less, some microhabitat types such as depressions may receive amounts of water several times the actual rain in the region due to active runoff and catchment areas. The size-class structure of *A. hierochuntica* populations was studied in the runnel and depression microhabitats of gravel and sand sites during the late spring-early summer seasons of 2003–2005. The gravel site is located in Wadi Hagoul (around 70 km east of Cairo), and the sand site is located in the desert of the Bahareya Oasis (around 300 km south-west of Cairo). The mean annual rainfall in both study sites is less than 80 mm [23].

The number of individuals belonging to each size-class was recorded and the percent of contribution relative to the total number of individuals was estimated in the different microhabitats. All individuals in $5 \times 5\ m^2$ quadrants were uprooted, sorted into size-classes and measured. Five replicates were used. Dry skeletons of *A. hierochuntica* were allotted into different size-classes (Table 1), according to crown volume. The crown of the skeleton has a spherical shape so the volume (cm^3) was measured by the equation: $4/3\pi\ d^2$, where‘d’ is the mean radius of the crown [2,3]. For each of the differentiated size-classes, growth and dry matter allocation traits were taken. These measurements included: root depth and shoot height, root/shoot ratio, mean diameter and number of fruits per individual skeleton. Each plant was separated into root, stem, and reproductive organs, and then oven-dried and weighed to estimate the pattern of phytomass allocation across different organs.

Greenhouse experiment

Dry skeletons of *A. hierochuntica* were collected from naturally growing populations in Wadi Hagoul. Seeds were liberated

Table 1 Volume range of *A. hierochuntica* size-classes.

Size-class	Volume range (cm^3)
1	< 1
2	1–2
3	2–4
4	4–8
5	8–16
6	16–32
7	32–64
8	64–128
9	128–256
10	> 256