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Seedling growth response of *Seriphidium quettense* to water stress and non-water stress conditions

Crecimiento de plántulas de *Seriphidium quettense* con y sin estrés hídrico

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Abstract. Seedling growth and development of *Seriphidium quettense* were examined under water stress (WS) and non-water stress (NWS) conditions. Seedlings were grown in pots to investigate their response to NWS conditions. Impact of WS on seedling growth was assessed in pre-existing plants grown under a semi-arid, natural environment. Seedling growth attributes were recorded on a monthly basis. Seedling growth exhibited a significant positive response under NWS conditions. Length of the main root axis at the first leaf emergence stage was 5.69 cm under NWS conditions; however, it was 4.8 cm in the natural environment (WS). At the end of the growing season, length of their primary root was 118 cm in NWS conditions. At the same time, it reached 8.8 cm in the WS natural environment. Lateral roots emerged from 2.09 cm of the main root axis, and a high lateral root density was found in the 2-10 cm region. The average lateral root length of NWS plants by the end of the first growing season was 33.07 cm, whereas in the WS environment it was 21 cm. Shoot length was 0.34 and 27.4 cm at the beginning and end of the growing season, respectively, under NWS conditions. In the natural WS environment, shoot length was 0.78 and 21 cm at the beginning and end of the same growing season, respectively. Under NWS conditions, seedlings remained green all year round, and 41% of the seedlings reached their physiological maturity. Mean values for number of panicles/plant, panicle length, number of floral branches/panicle, length of floral branches, number of florets/capitulum, and number of seeds/capitulum were 3.6, 16.77 cm, 43.7, 5.46 cm, 3.89, and 1.12, respectively, on seedlings which reached reproductive maturity. However, seedlings didn't exhibit a similar response in the natural WS environment. Our results support that *Seriphidium quettense* has a substantial potential for establishment and population propagation if supplemental water is provided during their first year of growth.

Keywords: *Seriphidium quettense*; Root and shoot growth; Water stress.

Resumen. El crecimiento y desarrollo de las plántulas de *Seriphidium quettense* se examinó bajo condiciones con o sin estrés hídrico. Las plántulas crecieron en potes para investigar su respuesta a estas condiciones. La respuesta del crecimiento de las plántulas ante condiciones de estrés hídrico se midió en plantas que ya estaban creciendo bajo condiciones semiáridas naturales. El crecimiento de las plántulas se midió mensualmente. Dicho crecimiento exhibió una respuesta positiva significativa ante condiciones de agua no limitantes. La longitud del eje principal de la raíz en el estado fenológico de primera hoja producida fue de 5,69 cm bajo condiciones no limitantes de agua; sin embargo, éste fue 4,8 cm bajo condiciones naturales. Al final de la estación de crecimiento, la longitud de la raíz primaria fue de 118 cm bajo condiciones no limitantes de agua. Al mismo tiempo, dicha raíz alcanzó 8,8 cm bajo condiciones naturales. Las raíces laterales emergieron a partir de 2,09 cm del eje principal de la raíz. Se observó una alta densidad de raíces laterales en la región de 2-10 cm de dicho eje principal. La longitud de las raíces laterales promedio en las plantas que no estuvieron limitadas por agua fue de 33,07 cm hacia el final de la primera estación de crecimiento. Esta longitud sólo alcanzó 21 cm en las plantas expuestas a estrés hídrico. Las longitudes de los tallos al inicio y final de la estación de crecimiento fueron de 0,34 y 27,4 cm, respectivamente, bajo condiciones no limitantes de agua. Cuando las plantas crecieron bajo condiciones naturales, sin embargo, dicho crecimiento fue de 0,78 y 21 cm al comienzo y final del ciclo de crecimiento. Bajo condiciones no limitantes de agua, las plántulas permanecieron verdes todo el año, y 41% de las mismas alcanzaron la madurez fisiológica. En estas plantas, los valores promedio para número de panojas/planta; longitud de la panoja; número de ramas florales/panoja; longitud de las ramas florales; número de flores/capítulo, y número de semillas/capítulo fueron 3,6; 16,77 cm; 43,7; 5,46 cm; 3,89, y 1,12, respectivamente. Sin embargo, las plántulas no exhibieron una respuesta similar bajo condiciones naturales de crecimiento. Nuestros resultados sustentan que *S. quettense* tiene un buen potencial para establecerse, y permitir la propagación de la población, si crece bajo condiciones no limitantes de agua durante el primer año de crecimiento y desarrollo.

Palabras clave: *Seriphidium quettense*; Crecimiento de tallos y raíces; Estrés hídrico.

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INTRODUCTION

Shrubs provide many benefits to humans and animals including food for livestock and wildlife, control of soil erosion, and medicine and other industrial products (McKell, 1989). *Seriphidium* and *Artemisia* species are the dominant dwarf shrubs in rangelands of the semi-arid region of northern highlands of Balochistan. *Seriphidium quettense* (Podlech) provides forage to small ruminants, when other plant species produce little dry matter particularly under drought conditions.

Because the world's water supply is limiting, future food and fodder demand for rapidly increasing population pressures are likely to further increase the importance of water stress (WS) studies (Somerville & Biscoe, 2001). The severity of WS is unpredictable as it depends on many factors such as occurrence and distribution of rainfall, evaporative demands and moisture storing capacity of soils (Wery et al., 1994). In arid and semi-arid areas, resource acquisition is one of a function of rooting depth and root distribution (Manning & Groenveld, 1989). In arid and semi-arid rangelands, re-establishment of dominant, native plant species is vital to maintain function, structure, diversity, and stability of landscapes. Water is one of the most limiting factors for plant growth in such habitats. Scarcity of water is a severe abiotic environmental stress to plant productivity. Water stress reduces leaf size, stem extension and root proliferation, disturbs plant water relations and reduces water-use efficiency (Farooq et al., 2008). Water and nutrients play central roles in growth and development of plants. These processes are the source of circulation and supply of nutrients to various organs and cells of the plant body. Water relations play a key role by influencing the distribution of plants in arid regions. Growth constraints of above ground plant parts can be conserved in favor of root development (Booth et al., 1990). Plants often respond to water, light, or nutrient limitations by increasing the efficiency with which limiting resources are invested into the production of biomass (Bloom et al., 1985; Chapin et al., 1987).

Therefore, the present study was aimed to investigate growth responses of *Seriphidium quettense* seedlings to non-water stress (NWS) field conditions in their first year of growth, and compare these responses with those obtained under natural WS conditions.

MATERIALS AND METHODS

The field experiment was conducted in Chiltan National Park, Hazargangi, Quetta. The experiment was conducted in an extended area of the park that was protected from livestock grazing since 1998. The soil of this area is sandy loam (Marwat et al., 1992). Pre-existing seedlings were selected from the natural field exclosure during April 2004. The seedlings outside of 16 plots made for another experiment (Gul et al., 2007) were considered in this regard. Seedlings were marked with thin colorful wires. Five seedlings were dug out from the soil at each sampling date. In the first three months, 50 cm circumference of soil surrounding each seedling was excavated to maximize the chances of complete root excavation from the soil. Later on, the length of circumference was increased to 1 m for the remaining samplings.

To assess seedling growth and development of *Seriphidium quettense* under NWS conditions, seeds were collected in December 2003 and sown in plastic pots in the next year during early spring. Pots were 12 inches (30.5 cm) in height and 8 inches (20.3 cm) in diameter. Soil was collected from Chiltan National Park Hazarganji from the place adjacent to other 16 plots utilized for another experiment (Gul et al., 2007). After collection up to 15 cm depth, soil was air dried, and passed through a 4 mm sieve to remove stones. Pots were exposed to natural environmental conditions and watered on alternating days to keep the upper soil surface wet for maximum germination. The trial was conducted in the Arid Zone Research Centre (AZRC), Quetta.

After emergence, plants were thinned to one per pot. Plants closest to the pot center were kept for experimental purposes. The first sampling was done at the first leaf stage on seedlings in March 2004. Later on, samplings were carried out at 30-day-intervals. Ten pots were used in the first sampling date (March), while the pot number was reduced to five in the remaining sampling dates. Monthly increases in shoot growth, root growth, and number of lateral roots were measured. For removal of seedlings, pots were carefully cut from the sides, and thereafter placed in water tubs during one hour. Seedlings were then carefully removed and washed with water. Main root axis and shoot length, and number of lateral roots were recorded. Number of lateral roots per 10 cm region of the main root axis was also recorded for the August and September samplings. In this connection, five samples (plants) were used in each month. Fifteen samples were used to measure the emergence point of the uppermost lateral root from the main root axis. Eight samples in October were used to measure length of lateral roots.

At the anthesis stage, ten plants were randomly selected for measuring the number of panicles/plant, panicle length, number of floral branches/panicle, length of floral branches, number of florets/capitulum, and number of seeds/capitulum.

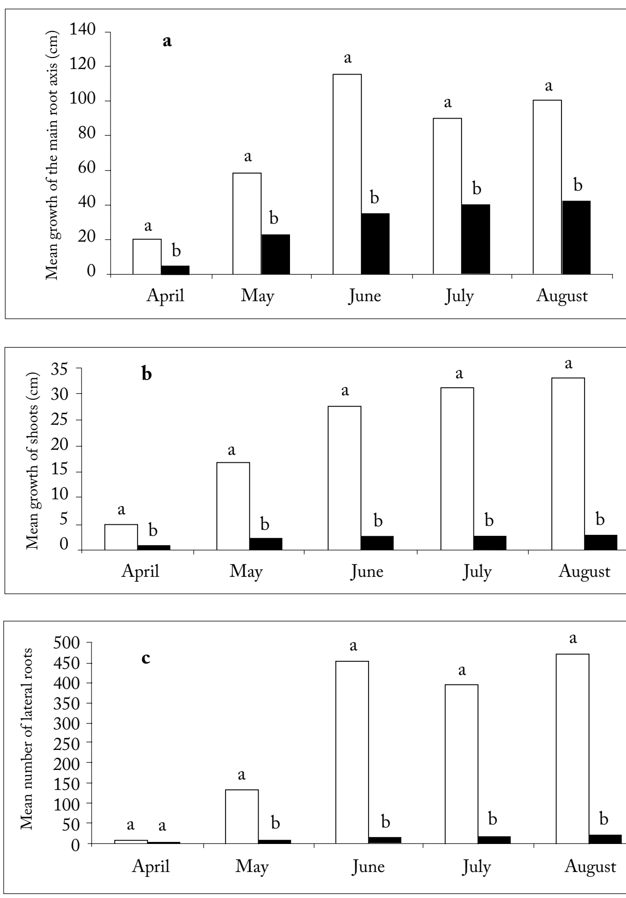
For seedlings grown under NWS conditions, data of shoot length, length of the main root axis, number of lateral roots, and density of lateral roots every 10 cm on the main root axis were subjected to one factor Complete Randomized Block Design (CRBD). Mean values, standard errors and range values for panicle length, number of floral branches/panicle, length of floral branches, number of florets/capitulum, number of seeds/capitulum, emergence point of the uppermost lateral roots from the main root axis, and length of lateral roots were calculated. Means and standard errors were also calculated for root length, shoot length, and number of lateral roots on seedlings grown in the WS natural environment.

Data obtained were subjected to two-sample t-test for independent samples to compare the growth rate of seedlings grown in the NWS conditions *vs* seedlings grown in the natural WS environment within each month.

RESULTS

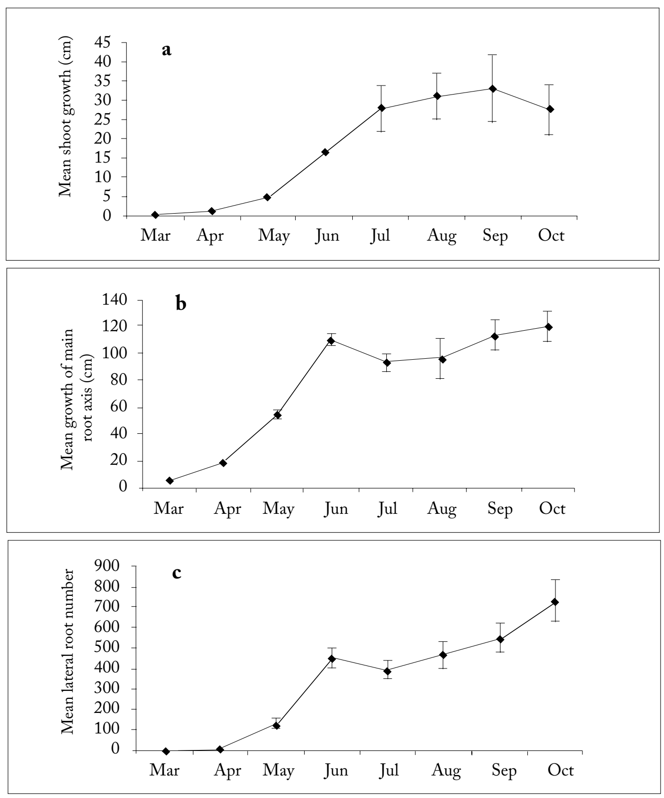
Growth of roots, shoots and number of lateral roots were significantly higher (p<0.05) on the plants grown under NWS than WS conditions (Fig.1 a-c).

Fig. 1. Monthly increase in growth of main root axis (a), shoot growth (b), and number of lateral roots (c) under NWS conditions (□) vs WS natural environment (■).
Within each panel, values with different letters during a given month indicate significant differences (p<0.05).
Fig. 1. Incremento mensual en el (a) crecimiento del eje radical principal, (b) crecimiento de la parte aérea, (c) número de raíces laterales, bajo condiciones sin (□) o con (■) estrés hídrico. Dentro de cada panel, los valores con letras diferentes durante un mes dado indican diferencias significativas (p<0,05).



The monthly increase in length of the main root axis, shoot length, and number of lateral roots on seedlings grown under NWS conditions was significant (Fig. 2). Mean shoot length in April was 0.34 cm while that in October was 27.4 cm (Fig. 2a). Plants continued their growth until late summer. Differences in the number of secondary roots every 10 cm in the main root axis were significant for both sampling dates. Density of secondary roots was significantly higher in the 1-10 cm region than at any other distance from the main root axis (Fig. 3).

Fig. 2. Monthly growth increment in shoot length (a); length of the main root axis (b), and number of lateral roots (c). Each symbol is the mean ± 1 S.E.
Fig. 2. Incremento mensual en el crecimiento de (a) la longitud del tallo, (b) longitud del eje de la raíz principal, y (c) número de raíces laterales. Cada símbolo es el promedio ± 1 E.E.



For seedlings grown in the WS environment, shoot length in April was 0.78 cm, while it was 2.94 in August. In April, mean root length was 4.8 cm; it increased to 38.8 cm in August. In April, the average number of lateral roots was 4, while it was 21 at the end of growing season (August) (Fig. 4). Seedlings attained higher growth rates in the earlier than later growing season, and high root to shoot ratios.

Seedlings grown under NWS conditions remained green throughout the year, and 41% of them reached physiological maturity. Flowering bud initiation started in late May, and flowering occurred in October. Seedlings, which reached reproductive maturity, showed the following values for number of panicles/plant, panicle length, number of floral branches/panicle, length of floral branches, number of florets/capitulum, and number of seeds/capitulum: 3.2, 16.77 cm, 43.7, 5.46 cm, 3.89, and 1.12, respectively. The number of florets and number of seeds/capitulum ranged from 3-6 and 0-4, respectively (Table 1). The mean emergence point for the uppermost lateral roots from the main root axis was 2.09 cm, and the mean length of lateral roots in October was 33.07 cm (Table 2). Seedlings grown under WS natural conditions showed leaf senescence in September, and no seedlings attained reproductive maturity.

Fig. 3. Number of lateral roots per 10 cm increments from the starting point in the main root axis, in the September (a), and October samplings (b). Each symbol is the mean ± 1 S.E.
Fig. 3. Número de raíces laterales cada 10 cm de incremento desde el punto inicial en el eje principal de la raíz, en los muestreos de Septiembre (a) y Octubre (b). Cada símbolo es el promedio ± 1 E.E.

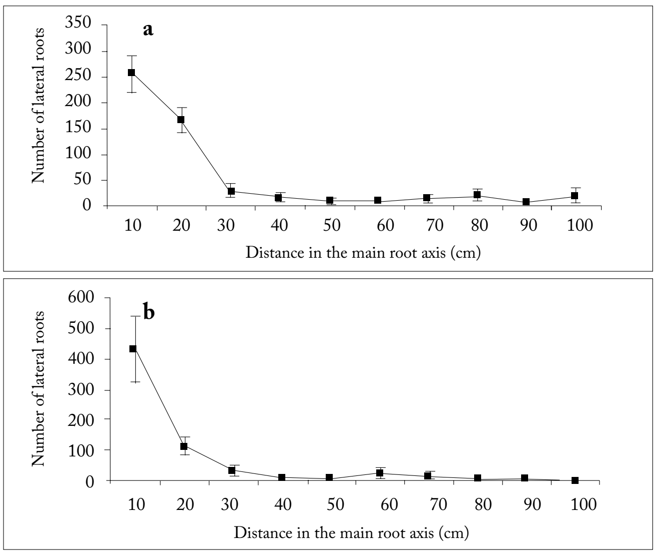


Fig. 4. Monthly growth of shoot and main root length, and number of lateral roots of *Seriphidium quettense* seedlings under NWS conditions during 2004. Each symbol is the mean ± 1 S.E.
Fig. 4. Crecimiento mensual del tallo y de la longitud radical principal, y número de raíces laterales de plántulas de *Seriphidium quettense* bajo condiciones sin estrés hídrico durante 2004. Cada símbolo es el promedio ± 1 E.E.

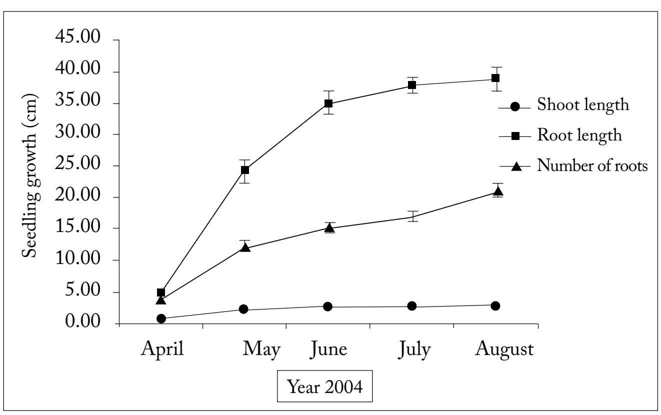


Table 1. Mean ± 1 S.E. and ranges of reproductive parameters for *Seriphidium quettense* seedlings grown under NWS conditions.
Tabla 1. Promedio ± 1 S.E. y rangos de parámetros reproductivos en plántulas de *Seriphidium quettense* que crecieron sin estrés hídrico.

Parameters	Mean ± S.E.	Range
Number of panicles/plant	3.2 ± 0.8	1-10
Panicle length (cm)	16.77 ± 1.5	5-35
Number of floral branches/panicle	43.7 ± 12.5	4-145
Length of floral branches (cm)	5.46 ± 0.27	0.6-19.5
Number of florets/capitulum	3.89 ± 0.06	3-6
Number of seeds/capitulum	1.122 ± 0.036	0.0-4

Table 2. Mean ± 1 S.E. and range of lateral root parameters for *Seriphidium quettense* seedlings (October sampling) grown under NWS conditions.
Tabla 2. Promedio ± 1 S.E. y rango de los parámetros de raíces laterales en plántulas de Seriphidium quettense (muestreo de Octubre) que crecieron sin estrés hídrico.

Parameters	Mean ± S.E.	Range
Length of lateral roots	33.07 ± 2.44	10-72
Panicle length (cm)	2.086 ± 0.152	0.5-2.8

DISCUSSION

Like in other arid and semi arid areas of the world, water is the most limiting factor for plant growth in Balochistan (MacMahon & Schimpf, 1981). However, when water is not limiting, nitrogen may be regarded as the limiting factor for plant growth in arid environments (Skujins, 1981). Results of the present study indicated that under non-water stress environments, *Seriphidium quettense* showed a fast growth habit. Monthly growth increments in shoot and main root axis length indicate that the study plant species invested more energy for rapid shoot and root growth under favorable environments. However, under water stress conditions, the limited aboveground growth may allow plants of this species to invest more energy into rapid root growth (Booth et al., 1990); this may enable these plants to survive in arid environments (Gul et al., 2007).

In arid and semi-arid habitats, resource acquisition is one of a function of rooting depth and distribution (Manning & Groenveld, 1989). Welch & Jacobson (1988) reported that seedling root length 40 days after emergence was 413, 455, and 358 mm in *Artemisia tridentata* spp. *wyomingensis*, *Artemisia tridentata* spp. *tridentata*, and *Artemisia tridentata* spp. *vaseyana*, respectively, in a greenhouse study. Seedlings of *S. quettense* in our study exhibited an extensive root system which had a high density of lateral roots in the uppermost region of the main root axis. Research also revealed that the ability of the seedlings to produce a high number of lateral roots in the uppermost region of the root system may enable plants to take advantage of the small precipitation events during the warm season. This will very likely play an important role in seedling survival of this species during the warm, dry season (Donovan & Ehleringer, 1994).

Seedlings remained green throughout the year in the water-unlimited environment; moreover, they continued growing in the summer season. However, leaves of this species senesced in the natural environment during the summer. Leaf senescence in dry, warm conditions has also been reported for *Artemisia tridentata* (Evans & Balck, 1993). Continued vegetative growth of this species under non-limiting water conditions may help their plants to acquire more natural resources for reproductive success. This may help to explain that 41% of the seedlings reached reproductive maturity, and produced seeds, in their first year of growth. At the same time, plants remained vegetative under natural conditions (personal observation). Positive water effects on increasing grain yield have also been reported for *Triticum aestivum* (Waraich et al., 2007). It also appeared that *Seriphidium quettense* seedlings invested most of the resources for belowground rather than aboveground growth under dry conditions. Maximum growth rate of seedlings took place early in the growing season when conditions were more favorable for plant growth and development, enabling plants to survive in arid environments (Booth et al., 1990).

Seedlings of *Seriphidium quettense* offer much promise for its successful establishment in degraded rangelands, and a good potential for its population increase, if water is not a limiting factor during their first year of growth.

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