

Abstract

Among factors controlling survival and establishment of range plant seedlings, amount and distribution of rainfall are particularly important in arid regions such as Saudi Arabia. Seed source could be considered an important factor controlling the response of seedlings to those two factors as the possibility exist for having genetic variations due to variations in ecological conditions in which different populations originated. Seedling survival and establishment of *Hammada elegans* (Bge.) Botsch. and *Achillea fragrantissima* (Forssk.) Sch-Bip. grown from seeds collected from three different areas in Saudi Arabia ; Riyadh , Al-Qassim and Al-Joaf were investigated in response to three amounts of rainfall ; 100 , 200 and 400 mm and two periods between two effective rains ; 7 and 14 days.

The aim of the study was to 1) determine the amount of rainfall required for survival and establishment of *H. elegans* and *A. fragrantissima* seedlings and therefore choosing the suitable sites for revegetation , 2) determine the effect of rainfall distribution on seedling survival and establishment and 3) study for the possibilities of variations in seedling survival and establishment among three populations of the two species in response to amount and distribution of rainfall.

The study was conducted into two main phases. The first phase included description of habitat in which the two species occur, seed collection, germination tests and determination the initial amount of rainfall required for germination and emergence of seedlings. The second phase covered the main study. Seeds of both species were sown in plastic tubes (50 cm X 16 cm) filled with soil (from Derab area) similar to that in which the species naturally occur. The experiment was laid out in a split-split plot design in 5 replicates.

Based on the preliminary studies, 15 seeds were sown in each tube , then thinned to three seedlings at the end of the first month, and irrigated with an amount of water equivalent to 30 mm rainfall. The amount of water equivalent to what is left after subtracting the applied initial amount of rainfall was distributed over a period of three months (wet period) either every seven or fourteen days. At the age of 3 months, seedlings were left without irrigation for two months (dry period). Several parameters were recorded. In *H. elegans*, these included : seedling height and root depth at different ages (30, 90, 120 and 150 days) , shoot and root dry weight and percentage dry matter at the end of wet and dry periods, weekly changes in number of seedling starting from irrigation stopage and

number of seedlings that extended their roots beyond 45cm deep at the end of the experiment. Those seedlings were considered vigorous and established.

For *A. fragrantissima*, seedling height and root depth were measured 30 days after sowing and the ratio between shoot length and root length was calculated. Root depth was also measured 90 days after sowing. Since most of *A. fragrantissima* seedlings died during their third month of age, an experiment was carried out in a controlled environment to test whether seedlings loss were due to improper sowing time or sensitive to drought conditions.

The results of the study could be summarized as follows:

1- *Hammada elegans*

1- Amount of initial rain required for germination and seedling emergence .

H. elegans required an amount of 10 mm or more initial rain for seed germination and seedling emergence . However, best results were found between 20- 30 mm .

2- The effect of rainfall

Positive effect was found on all growth characteristics as the amount of rainfall increased. Root depth increased with increasing rainfall especially during the wet period although no significant differences appeared in terms of root growth rate during the dry period between different amounts of rainfall received . Shoot growth rate increased in response to increase in rainfall during the wet period. Thus, seedling grown under high rainfall was more vigorous even during the dry period . During the dry period, seedlings grown under high average rainfall were high in shoot dry weight and shoot / root ratio, although no differences were found between 200 and 400 mm rainfall.

As rainfall increased, seedling survival increased significantly. The final percentage survival was 6.8 , 17.8 and 47.5 % under 100 , 200 and 400 mm rainfall respectively. The highest rainfall gave the highest percentage of seedlings having over 45cm root depth, indicating that increase in average rainfall produces vigorous seedlings that are capable of continuing growth during the dry season and will have greater chance of survival and establishment than those growing under low average rainfall.

3- Effect of period between two effective rains

No significant effects of period between two effective rains were found in growth parameters of seedlings with the exception of root length at 120 days from sowing. At this age, seedlings receiving water every 14 days had greater depth

than those receiving water every 7 days. This result was reflected on root growth rate which was significantly higher under 14 days than 7 days treatment during the dry period. This indicates that increase period between two consecutive effective rains may encourage seedlings to advance their roots deeper in the soil, thus favored when seedling growth rainfall season is over.

Increase period between two effective rains to 14 days had a positive impact on seedling survival and establishment. There were more survived seedlings in tubes receiving water every 14 days during the dry period until the end of the experiment than those irrigated every 7 days, although the differences were not significant. The percentage of seedlings having root length of 45 cm or more were 9.2 % and 3 % for 14 days and 7 days periods respectively. This emphasizes the previously discussed results of favored growth traits under the period of 14 days between effective rains. Increase of time to 14 days between effective rains hardened the seedlings and encouraged root elongation. Therefore, seedlings had greater growth rate during the dry period which resulted in vigorous seedlings able to survive and establish for the rest of the dry season.

4 - Effect of populations

There were some differences in seedling growth parameters among seeds collected from the three populations. Seedlings from Al-Qassim and Riyadh populations had greater height than those from Al-Jouf and had higher shoot growth rate during the wet period but no significant differences were detected among populations in root growth rate at any time. Also, there were no significant differences between seedlings from different populations in survival or establishment. However, seedlings from Al-Qassim and Riyadh had higher percentage of survival and establishment than that from Al-Jouf populations.

5- Effect of seedling growth characters on survival and establishment

To understand the effect of growth parameters on seedling survival and establishment, simple correlations were performed between all growth traits and seedling survival and establishment. Significant correlations were found between every single trait and seedling survival and establishment. However, these correlations per se do not indicate which traits have direct impact on survival and establishment of seedlings. Therefore, multivariate analysis approach was adopted to search for growth characteristic(s) that have the great effect on seedling survival and establishment. Factor analysis was used to determine the growth traits that best describe seedling survival and establishment.

To determine the direct and indirect effect of growth traits on seedling survival and establishment, path coefficient analysis was used. The results indicated that among the studied traits, shoot dry weight and root depth during the dry period had direct and significant effect on seedling survival (0.77 , 0.76) and an indirect effect through the rest of studied traits. Shoot growth rate during the dry period came next to the two mentioned traits in its effect on seedling survival (0.39). The effects of growth traits on seedling establishment were positive. Seedling height and shoot dry weight had the greatest direct effect on seedling establishment. Also, they had the greatest indirect effect on seedling establishment. These results indicate that seedling height is a useful non-destructive tool in field evaluation of seedling establishment.

II - *Achillea fragrantissima*

A. fragrantissima required an amount of 10 mm or more initial rain for seed germination and seedling emergence. However, best results were found between 20- 30 mm.

Seedlings of *A. fragrantissima* had their greatest height under the highest rainfall average after 30 days from sowing although no significant differences were found between different rainfall averages. Root depth also increased with the increase of rainfall. No significant differences were detected on the effect of periods between effective rainfall or population on any studied parameter. Most of *A. fragrantissima* seedlings died at their third month age. In a study to investigate effect of sowing time on seedling growth, results indicated that the best time for seed sowing was February followed by sowing in March. No significant differences were detected in most of studied growth traits neither between time of sowing nor among populations. The results indicate that seedling loss of *A. fragrantissima* was caused by sudden rise in temperature which led to leaf senescence and death in spite of having adequate soil moisture reserves as roots were not able to cope with leaf transpiration.

Conclusions

1- seed germination and seedling emergence of both species require 10 mm or more with greater results under 20 - 30 mm.

2- Increase in rainfall application to 400 mm increased shoot and root growth rate during the rainy season. These results were reflected on vigorous seedlings during the dry season which helped in increasing the chance for survival and establishment of *H. elegans*. It is concluded that this species could be revegetated

in areas using some mechanical methods that collect rainfall water such as pitting and contour furrowing.

3- Increasing period between effective rains gave chance to seedling hardening during the wet period and encouraged them to deepen their roots . consequently, they had greater ability in survival and establishment .

4- No significant differences were found between populations of *H. elegans* in terms of survival and establishment although population from Al-Qassim and Riyadh had greater growth rate than Al-Jouf population .

5- It is possible to rely on some growth traits which gave direct and indirect effect on both survival and seedling establishment especially those easy to measure such as seedling height and growth rate when evaluating seedling vigor and its ability to survive and establish in any attempt to improve seedling establishment of range plant species in future studies.

6- The study indicated that there are further measurements which should be considered when evaluating the response of seedling establishment to ecological factors. These measurements may include the pattern of shoot branching, root function and distribution and total non-structural carbohydrates in seedlings.