Seedling survival and establishment of *Hammada elegans* as affected by the amount and frequency of rainfall

ABDULAZIZ MOHAMMAD ASSAEED, ABDULLAH ABDULAZIZ AI-DOSS &
ABDULAZIZ ABDULLAH AI-QARAWI

ABSTRACT: *Hammad elegans* is considered a valuable range plant species in Saudi Arabia. It is browsed by camels and sheep. Also, it is a promising species in range reseeding, land reclamation and sand stabilization. This study was conducted to examine the effect of varying amounts of rainfall and the time between two effective rains on seedling survival and establishment of *Hammada elegans* from three populations (Riyadh, AI-Qassim and AI-Jouf). Irrigation water equivalent to 100, 200, or 400 mm rainfall was applied either at seven or 14 day intervals for three months. Seedlings were then left without irrigation for another two months before survival and establishment were determined. Seedling survival increased significantly from 6.8% to 47.5% as the amount of rainfall increased from 100 to 400 mm. Establishment, however, was not affected by the amount of rainfall. Also, there were significant differences between seven and 14 days between two effective rains in terms of establishment. Plants from AI-Jouf population tended to be the lowest in both traits.

KEYWORDS: Revegetation, pitting, contour furrowing, irrigation, soil moisture, roots, seedling growth shoots, Saudi Arabia.

1 INTRODUCTION

Amount and distribution of rainfall are the most important factors controlling seedling survival and establishment of range plants in arid areas. Several researchers (Frasier & Simanton, 1987; AI-Farraj, 1990; Johnson & Aguirre, 1991) have indicated that soil moisture availability during the rainy season regulates seedling emergence, biomass, root growth, survival and establishment. Furthermore, rainfall distribution over the season affects seedling growth and, hence, survival and establishment of seedlings (Hassanyar & Wilson, 1978; Wester et al., 1986). Valentine (1989) emphasized the importance of selecting the right seed source to revegetate a particular range site as different plant populations may have developed some adaptive responses to local environmental conditions.

Hammada elegans (Bge.) Botsch. is a widely spread perennial shrub in Saudi Arabia. It is browsed by camels and sheep. The species is useful as sand stabilizer. It is considered a promising species in revegetation projects (Clor et al., 1976; 1989). No

Table 1. Effect of amount and distribution of rainfall on some growth attributes of *Hamada elegans* Seedligs from three geographical regions, Saudi Arabia.

	Seedling height (mm)		Root length (mm)		Total biomass (g)		R/S ratio		RGR (mm/d)	
	4 months	5 months	4 months	5 months	4 month	5 months	4 months	5 months	wet period	dry period
Rainfall (mm)										
100	43.2	77.7	242.4	413.6	0.142	0.412	1.457	1.619	0.0352	0.0604
200	63.2	108.2	256.2	358.2	0.237	0.397	1.065	1.333	0.0393	0.0683
400	106.1	99.0	332.9	339.4	0.573	0.420	1.047	1.269	0.0392	0.0645
$LSD_{0.05}$	26.18	NS	62.64	NS	0.3020	NS	NS	NS	0.003	NS
Period (d)										
7	73.0	94.7	248.1	323.0	0.271	0.352	1.079	1.233	0.0378	0.0604
14	71.3	102.1	304.5	368.5	0.369	0.451	1.262	1.399	0.0380	0.0684
$LSD_{0.05}$	NS	NS	41.22	NS	NS	NS	NS	NS	NS	NS
Seed source										
Riyadh	71.6	80.8	264.3	361.0	0.322	0.428	1.601	1.855	0.0371	0.0628
Al-Qassim	87.1	128.6	314.2	354.0	0.415	0.446	1.155	1.208	0.0411	0.0671
Al-Jouf	56.4	80.0	254.9	333.6	0.217	0.346	0.725	0.990	0.0355	0.0640
$LSD_{0.05}$	17.25	20.57	34.18	NS	0.1783	NS	0.351	0.865	0.0032	NS

information is available on seedling establishment *of H. elegans,* therefore, this study was conducted to determine the effect of three amounts of rainfall (100, 200 and 400 mm) falling every seven or 14 days on seedling growth, survival and establishment of *H. elegans* collected from three geographical regions in Saudi Arabia (Riyadh, Al-Qassim & Al-Jouf).

2 MATERIALS AND METHODS

The study was conducted at the educational farm. College of Agriculture, King Saud University. Based on preliminary tests on seed germination and initial amount of water required for optimum seedling emergence, seeds of *H. elegaus* were sown in PVC tubes (15 cm diam. × 50 cm high) filled with a sandy loam soil as illustrated by Ellem (1974) and Sheley and Larson (1994). All tubes were initially irrigated with an amount of water equivalent to 30 mm rainfall (603 ml water) to insure optimum emergence. Thereafter, tubes were irrigated with amount of water equivalent to 100, 200 or 400 mm rainfall, after subtracting the initial amount of irrigation, distributed over a period of three months either weekly or every two weeks using seeds collected from three geographical areas in Saudi Arabia (Riyadh, Al-Qassim and Al-Jouf). Seedlings were then left without irrigation for two months. The experiment was laid out and analyzed as a split-split design (Gorniz & Gorniz, 1984; SAS, 1988). Main plots were occupied by the average annual rainfall treatments, sub-plots were occupied by the period between two rains (irrigation interval) and seed source was allocated to the sub-sub plots. Five replicates were used with four observation tubes in every experimental unit. Seedling height was recorded monthly. Root length, and shoot and root dry weights were determined by destructive sampling at four and five months of age. Starting from the first week when irrigation was ceased, seedling mortality was monitored weekly. At the end of the experiment, percentage of surviving seedlings was recorded. Seedlings having ≤ 45 cm long roots were considered capable of establishment (Thalen, 1979). Root/shoot ratio (R/S ratio) was calculated using root and shoot dry weights. Relative growth rate (RGR) during water addition period (wet period) and during the dry period was calculated according to Hunt (1983).

Residual soil moisture was determined gravimetrically (Hillel, 1982) at days 7, 30 and 60 from time of irrigation stoppage at 0-15 cm, 15-30 cm and 30-60 cm soil depths.

3 RESULTS AND DISCUSSION

3.1 *Seedling growth*

Seedling growth was generally affected by the amount of rainfall. Significant differences occured among levels of rainfall in terms of seedling height ($P < 0.05$), root length ($P < 0.05$) and total biomass ($P < 0.05$) at age of four months, however, these differences diminished one month later. RGR was also affected ($P < 0.05$) during irrigation time (wet period), but no differences were observed when irrigation was ceased (dry period) (Table 1). As the amount of rainfall equivalents were increased, seedlings had more vigorous growth in terms of seedling height, root length and total biomass of 4 mo old seedlings while seedlings growing under lower soil moisture had greater, although not-significant, root to shoot mass. This indicates that seedlings receiving more water took advantage of favorable soil moisture conditions by having vigorous growth, whereas those receiving less amounts of water allocated more assimilates towards root development as indicated by their higher R/S ratios. Apparently, loss of 'weak' seedlings under low moisture level due to greater mortality, thus, leaving only vigorous individual seedlings, may have resulted in less differences among levels of rainfall treatment at the end of the experiment.

Increasing time between consecutive rains from seven to 14 days resulted in significant increase ($P < 0.01$) in root length at age from four months (Table 1), indicating that seedlings receiving less frequent moist conditions were induced to produce deeper roots to catch up with drying soil. Similar results were given by Esler and Phillips (1994) for other species. All other measured traits has similar trends, but none was significantly affected. Only one significant interaction between amount of rainfall and period between two rains occured ($P < 0.05$) in root length at age of four months. With the exception of low amount of rainfall, root length increased in response to increase in amount of rainfall as the dry period between two rains was extended.

Seeds collected from different regions differed significantly in most of the seedling growth traits (Table 1). Seedlings from Al-Qassim were the highest in shoot height, root length, total biomass and RGR during the wet period while seedlings from Al-Joufwere the lowest in all mentioned traits. Seedlings from Al-Jouf also had the least R/S ratio and seedlings from Riyadh had the highest R/S ratio. These results indicated that seedlings from Al-Jouf were the least among the three populations in utilizing the available moisture under the specified conditions. This may have resulted from the least investment in root development as evidenced from the lower R/S ratios.

3.2 *Seedling survival and establishment*

Seedling mortality started as early as the first week of the dry period. By the third week, which coincided with high temperature, mortality rate increased, especially under the low amount of rainfall (Fig. 1). At week six, the rate of mortality under the moderate rainfall (200 mm) increased steadily while seedling mortality under the high rainfall was relatively stable (Fig. 1). At the end of the experiment, seedling survival at 400 mm was significantly higher than the other two levels. Seedling survival increased from 6.7% in 100 mm rainfall to 47.5% for 400 mm rainfall (Table 2). These results are in agreement with findings of Distel et al. (1992) on *Piptochaetium napostaense* and *Stipa tennuis*. Seedling establishment increased with increase in amount of rainfall, although not significantly (Table 2). Seedlings growing in more favorable moisture conditions grew vigorously, had deeper roots and greater relative growth rate during the rainy season, thus, had greater ability to withstand the drying conditions. Residual soil the moisture (Table 3) indicates significantly higher moisture availability under 400 mm rainfall treatment throughout the soil profile during the dry period, with the exception of the 30-45 cm layer at the end of the experiment. This further explains higher survivorship under the high amount of rainfall imposed. While soil moisture under the 100 and 200 mm rainfall dropped below the wilting point of the soil (4.28%), there were considerable numbers of seedlings remaining alive. This indicates the capability of *H. elegans* to tolerate moisture stress. Most perennial shrubs are known to tolerate soil moisture stress. Osmond et al.

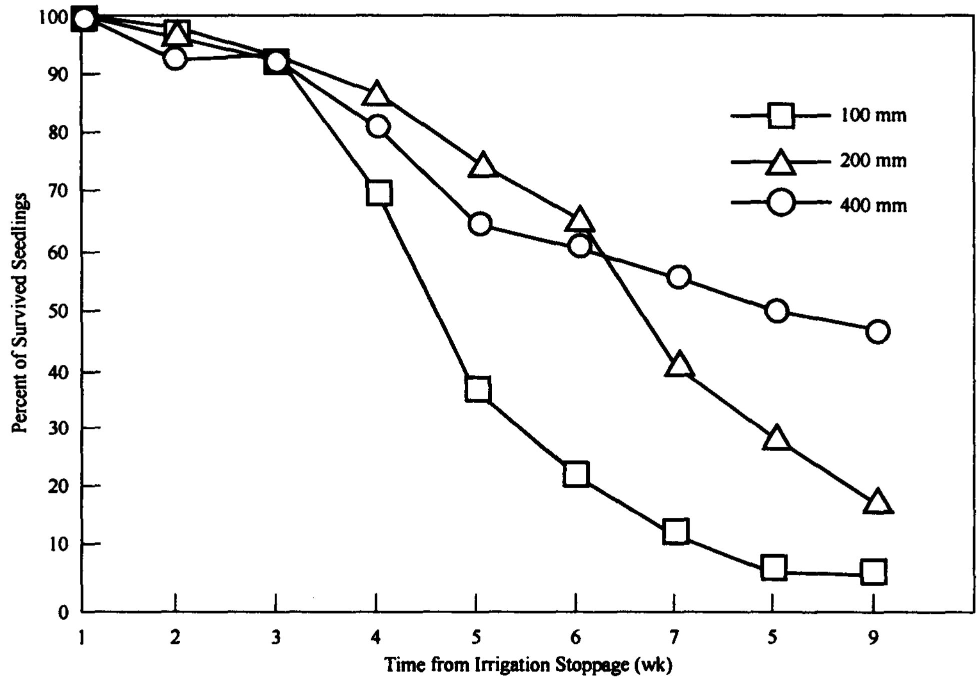

Figure 1. Effect of amount of rainfall on seadling survival of *H. elegans*.

Table 2. Percentage survival and establishment of *Hammada eleganss* seedlings five months after seed sowing as influenced by the amount and distribution of rainfall for three different seed sources.

	Percentage survival	Percentage establishment
Rainfall		
100	6.76	3.07
200	17.82	3.92
400	47.46	11.31
$LSD_{0.05}$	12.54	NS
Period (d)		
7	18.56	2.99
14	29.21	9.17
$LSD_{0.05}$	NS	5.01
Seed source		
Riyadh	24.14	7.19
Al-Qassim	26.55	7.20
Al-Jouf	21.11	3.88
$LSD_{0.05}$	NS	NS

(1980) reported that several Atriplex species can thrive well in dry conditions because of their ability of water acquisition under as high as −15 bar water stress.

The period between two rains had no significant effect on seedling survival, despite differences in their growth traits, although percentage survival increased as the period

Table 3. Residual soil moisture associated with the different amounts of rainfall as determined 7, 30 and 60 d after irrigation stoppage.*

Time from irrigation stoppage (d)	Rainfall average (mm)	Residual soil moisture (%) 0-15 (cm)	15-30 (cm)	30-40 (cm)
7	100	3.15	5.31	5.87
	200	4.62	6.30	6.62
	400	7.53	8.75	9.47
$LSD_{0.05}$		1.12	1.01	1.01
30	100	1.54	3.30	4.31
	200	2.24	4.42	5.15
	400	2.73	4.49	5.79
$LSD_{0.05}$		0.40	0.69	0.79
60	100	1.49	2.76	3.90
	200	1.77	3.50	4.13
	400	2.35	4.23	4.38
$LSD_{0.05}$		0.21	0.86	NS

* No statistical differences were observed in rainfall distribution treatments or among seed sources.

extended from seven to 14 day. One explanation of this result may be the lack of significant differences in residual soil moisture between the two periods (results not shown). Similarly, no differences were observed among the three sources of seeds in seedling survival, possibly for the same reason.

When seedlings with low roots (45 cm long or more) were considered capable of establishment (Thalen, 1979), it is found that establishment varied from about 3% in 100 mm rainfall to 11.3% in high amount of rainfall, but no significant differences were observed. On the other hand, increase in period between two effective rains resulted in significantly ($P < 0.05$) higher seedling establishment. Extending the period between two rains may have caused seedling hardening, thereby, root penetration was encouraged (Table 1). It is therefore suggested that widening wetting and drying cycles may result in beneficial consequences by encouraging root penetration so as to have greater chance of establishment. This suggests that not only total amount of rainfall plays an essential role in seedling establishment, but the way it is distributed during the rainy season can also be an important factor. A similar conclusion is suggested by Wester et al. (1986). No differences were observed in percentage establishment of seedlings from different seed sources.

CONCLUSIONS

Higher amount of rainfall with expanded time between two rains produced deep rooted and vigorous seedling that were able to utilize residual soil moisture, therefore, increasing their chance of survival and establishment during the dry period. It is, therefore, concluded that successful revegetation with *H. elegans* would be expected in depressions where rainwater is collected from surrounding areas or by means of pitting and contour furrowing practices where soil moisture is concentrated in the vicinity of the root system.

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