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Mortality and Seedling Survival of Three Salt Marshes Species as Influenced by Timing of Precipitation.

تأثير تواقيت هطول المطر علي بقاء وموت بادرات نباتات السبخات الملحية التي تنمو في المملكة العربية السعودية.

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Abstract: The potential of mortality and seedling survival of three salt marshes species (*Atriplex farinosa, Aeluropus brevifolius, and Juncus rigidus)* as affected by timing of precipitation were measured. Three separate (14)-day experiments were conducted using (1),(2), (3), (4), and (5) days wet followed with (5) days dry. The number of emerging seedlings growing from (100) seeds placed in sand media in small plastic pots were counted daily. A total of (50%) to (70%) of *Juncus* seeds emerged in the initial wet period, but over (50%) of the seedlings died in the following (5) days dry period, resulting in less than a (35%) survival rate. The *Atriplex* was slower to germinate and seedling survival rate resulted (40%) - (60%), while it was slower than (20%) in *Aeluropus brevifolius*. The (1) and (2) days wet sequences the maximum until the final rewet period. The information offers the possibility of incorporating the probabilistic aspects of timing of precipitation and soil water relations into a description of the seedling environment.

Keywords: salt marshe species, plant establishment, mortality, survival, preciptation time, Saudi Arabia.

المستخلص: تهتم هذه الدراسة بتقدير مدي استجابة بقاء وموت بادرات ثلاث أنواع من النباتات الملحية التي تنمو في المملكة العربية السعودية (نبات الرغل، نبات العكرش و نبات السمار) مع تعاقب فترات من الجفاف والرطوبة. تم استخدام ثلاث طرق تعتمد علي بيانات حساب عد البادرات يوميا وذلك باستخدام (1) ، (2)، (3)، (4)، (5) أيام رطوبة يتبعها (5 أيام) جفاف (100) بذرة تنمو في وسط رملي. وقد دلت النتائج علي أن معدل الإنبات لنبات السمار يتراوح بين (50% إلى 70%) في فترة الرطوبة الأولى، بينما معدل وفيات البادرات خلال تتابع فترات 5 أيام الجفاف أكثر من (50%) ومعدل البقاء للبادرات أقل من (35%). بينما كان تأثير التعاقب المائي واضحا علي معدل وفيات بادرات نوع نبات الرغل بنسبة (60 %) بينما كان أقل من (20 %) في نوع نبات العكرش. برهنت النتائج علي أن أقصي معدل للبادرات تحققت بعد يومين رطوبة في نوع نبات العكرش. لمثل هذه الدراسات أهميتها في وضع تصورات محتملة لفهم خصائص إنبات وبقاء النباتات وأستجابتها لتواقيت سقوط المطر.

كلمات مدخلية: نباتات ملحية، إنبات بادرات، بقاء وموت، تعاقب جفاف ورطوبة، السعودية.

Introduction

Plant establishment from seed requires a viable seed and a favorable environment for seedling development. Environmental stresses of fluctuating temperatures, variable precipitation patterns, poor seedbed preparation, and plant competition make it difficult to develop an understanding of the interactions of the various components involved in plant establishment (Asay and Johnson 1987).

The timing and quantity of precipitation immediately following seeding are among the factors which significantly affect the success of rangeland revegetation efforts (Frasier *et al.* 1985). To diminish the risk of seeding failure in arid climates, it is necessary to better understand the factors involved in the process of seed germination. Also, because species vary in their requirements for germination and growth, it is necessary to study the responses of different species to arid conditions. Due to erratic precipitation and high evapotranspiration in arid lands, the soil moisture is often inadequate for seed germination and seedling establishment. Therefore, seed germination and seedling establishment are the most critical phases in revegetation of arid lands (Tapia and Schmutz 1970).

(Kassas 1955) found that soil moisture was the limiting factor for the distribution of the arid shrublet *Alhagi graecorum* Boiss. (Evetts and Burnside, 1972) showed that the seedlings of *Asclepias syriaca L.* were more susceptible to moisture stress than *Bassia indica.* Wight and less susceptible than those of *Apocymum cannabinum* L. and *Helianthus annuus* L. (Frasier *et al.* 1984) show that the initial germination and seedling survival of

Eragrostis lehmannina Ness. and *Bouteloua curtipendula* (Michx.) Torr. were directly affected by the relative lengths of the first wet and dry periods following seeding.

In non-irrigated areas, the soil water used in seed germination and plant establishment is replenished by precipitation and depleted by evaporation. In arid and semiarid regions the precipitation process is intermittent, with the periods of rainfall being much shorter than the intervening dry period. Temperature and solar radiation, which affect the loss of soil water by evaporation, are both interrelated with precipitation and are more likely to be below average on rainy days than on dry days (Richardson 1981). For *Agrostis stolonifera L.,* (Ahmed and Wainwright 1976) showed that ecotypes from both a salt spray zone and a salt marsh retained much less after immersion in salt water than did an inland ecotype. This study also was designed to determine the plant responses to time and quantity of precipitation during the germination and establishment stages of three salt marsh species. Such types of studies are important for constructing probability models of natural precipitation-drought combinations and developing a description of the seedling environment to guide in selecting the optimum time of seeding and a range of concentrations of salinity.

Materials and Methods

The seed samples used in the present study were those of *Atriplex farinosa, Aeluropus brevifolius and Juncus rigidus.* The mature seeds were provided from South-Western region of Saudi Arabia . Seed lots germination percentages (pure live seeds) (PLS) were:

* *Atriplex farinose* (75%).
* *Aeluropus brevifolius* (95%).
* *Juncus rigidus* (90%).

The studies were conducted in a laboratory germinator operated at an alternating temperature of (20°C) for (16) hours in darkness and (30°C) for hours in light. Plastic pots each (26 cm) in diameter and (16 cm) depth, with a layer of cotton placed in bottom. All pots were filled with fine sand soil. For each species, (100) seeds were sown on the dry surface of each pot and covered with a (2 - 3 mm) layer of dry sand. After sowing, watering sequences experiments were conducted (*Table 1*).

All pots initially received (20) grams of water (~10%) moisture by weight). The emerged seedlings in each pot were counted daily for a fortnight period. The total seedling count of the pots belonging to the same species in each water sequence was averaged. One additional experiment was conducted with the

Table (1): Wet-dry-wet watering sequences used in the experiments.

Experiment No.	Water sequences	Period (days)		
		Wet	Dry	Wet
1	2 - 2	2	2	01
	2 - 5	2	5	7
2	3 - 3	3	3	8
	3 - 7	3	7	4
3	1 - 5	1	5	8
	2 - 7	2	7	5

(1), (2), (3), (4) and (5) days wet followed with (5) days dry. The study design was (5) completely randomized blocks with (6) replications for each species. The number of live plants in each pot was counted each day.

There are (3) specific records, during the (14) day experiments, when the number of seedlings are of significant interest. These are the maximum number of seedlings (Nmax) resulting from the initial wet period, the minimum number of seedlings (Nmin) surviving the dry period, and the number of seedlings at the end of the second wet period when all surviving seeds have germinated (N14). The minimum number of germinated seeds (Gmin) was calculated following the formula of Frasier (1989):

$$Gmin = Nmax + N14 - Nmin.$$

Replication means of Gmin, Nmax, (N14) and (Nmin.) and germinated seeds were subjected to analysis of variance to determine differences between species and watering sequences. The daily plant counts were analyzed by analysis of variance techniques. Duncan's new multiple range test was used to evaluate differences among means

$$(P \dagger 0.05)$$

(Gouet and Philippeau 1986).

Results and Discussion

Atriplex farinosa has the maximum initial seedling count (Nmax) at the second day. But seedling emergence of the other species was not observed at that time. Their Nmax's were reached at days (3 - 5) (*Table 2*).

Table 2. Maximum number (Nmax.), of emerged seedlings during or following the wet period minimum number (Nmin) of seedlings after the application of dry period and number of seedlings at the end of the experiment (N14), for seed samples (each of 100 seeds) represent three salt marsh species with six wet-dry watering sequences. Numbers in parenthesis are the day of the

experiment. Values in columns and rows for a given period, followed by the same letter are not significantly different ($P < 0.05$).The minimum number of seedlings surviving the dry period (Nmin) occurred at days (4 to 10) for all species. For all experiments, there were significant differences in (Nmax), (Nmin) and (N.14) in relation to most species and water-sequences ($P < 0.05$). *Atriplex farinosa* has the highest (Nmax), (Nmin) and (N14), followed by *Aeluropus brevifolius* and *Juncus rigidus* for the (3) days initial wet period (Experiment No. 2), while *Juncus rigidus* had the lowest values with one or more wet days (in experiment No. 3). Across all species, there were more surviving seedlings with the (3-3) and (3-7) watering sequences while (Experiment No. 3) had the lowest values of emerged seedlings.

Ranking of species according to the initial seedling emergence response is *Atriplex farinosa, Aeluropus brevifolius,* and *Juncus rigidus.* Even with (3) wet days, initial seedling emergence of *Juncus rigidus* and *Aeluropus brevifolius* was very low. This study shows that *Atriplex farinosa* and Aeluropus brevifolius had good seedling establishment and seedling survival.

The daily plant count data for the (5) different wet - dry water sequances show that the *Atriplex farinosa* and *Aeluropus brevifolius* produced seedlings very rapidly, even with the short water sequences. The *Aeluropus brevifolius* was slower to germinate, and there was a more pronounced effect the length of the first water period on the initial plant count. (Frasier *et al.* 1985) mention two factors which affect the number of seedlings that survive the first wet-dry watering sequence: the number

Table (2): Maximum number of emerged seedlings during or following the wet period (Nmax.), minimum number of seedlings after the application of dry period (Nmin) and number of seedlings at the end of the experiment (N14).

Experiment No.	Water sequences (wet-dry) day	Species			X-
		Atriplex farinosa	Aeluropus brevifolius	Juncus rigidus	
Experiment No. 1					
Initial - N(max.)	2 - 2	(2)3.97a	(4)2.85cd	(3)5.53f	6.75
	2 - 5	(2)6.47b	(4)9.36c	(3)3.04e	6.95
	X-	6.97a	1.16b	9.73c	
Dry - N(mim.)	2 - 2	(4)9.87a	(5)0.94bc	(4)7.73d	2.55a
	2 - 5	(7)8.65b	(7)7.33e	(7)0.33e	2.14b
	X-	8.76a	3.14b	4.53c	
Final - N(41)	2 - 2	8.78a	4.65c	7.35cd	9.56a
	2 - 5	5.18b	5.64d	3.74d	4.85b
	X-	6.48a	4.15b	5.05c	
Experiment No. 2					
Initial - N(max.)	3 - 3	(2)2.88a	(5)4.17c	(3)7.26d	1.47a
	3 - 7	(2)1.47c	(4)5.18b	(3)0.15e	8.86b
	X-	2.18a	5.67b	8.65c	
Dry - N(mim.)	3 - 3	(6)7.58a	(6)3.36d	(6)7.33e	9.06a
	3 - 7	(9)3.17b	(9)8.56c	(9)3.03ef	8.55b
	X-	5.87a	6.46b	0.23c	
Final - N(41)	3 - 3	6.09a	7.56d	7.93e	3.56a
	3 - 7	3.87b	4.86c	3.23f	6.95b
	X-	4.48a	1.76ab	0.63c	
Experiment No. 3					
Initial - N(max.)	1 - 5	(2)6.55b	(4)9.63e	(3)0.22f	2.83b
	2 - 7	(2)2.36a	(4)6.05bc	(3)7.24bc	2.25a
	X-	4.95a	7.34a	4.23a	
Dry - N(mim.)	1 - 5	(6)6.93c	(6)3.02e	(6)6.41f	8.42b
	2 - 7	(9)0.55a	(9)0.64b	(9)3.53c	4.54a
	X-	3.74a	2.33b	9.42c	
Final - N(41)	1 - 5	4.47a	6.24c	7.63d	2.15b
	2 - 7	3.56ab	0.26b	3.73b	9.45a
	X-	8.96a	3.25b	0.73c	

** For seed samples (each of 100 seeds) represent three salt marsh species with six wet-dry watering sequences. Numbers in parenthesis are the day of the experiment. Values in columns and rows for a given period, followed by the same letter are not significantly different ($P < 0.05$).*

of produced seedlings in the first wet period which develop sufficient vigour to survive the subsequent dry period, and the number of ungerminated but viable seeds which remain after the first wet-dry watering sequence. They found that the initial germination and seedling survival of *Bouteloua curtipendula* (Michx.) Torr. and *Eragrostis lehmanniana* Nees. were directly affected by the relative lengths of the first wet and dry periods *Bouteloua curtipendula* may have the lowest drought tolerance, and *Eragrostis lehmanniana* and *Eragrostis curvula* var. *conferta* (Schrad.) Nees. have the highest drought tolerance. However, (Cox and Jordan 1983) report that with some species, there is the possibility that, with moderate length wet period, more seedling may initially emerge, but be in a growth stage that is susceptible to a drought. This study shows that the extra day of water produced more initial seedlings (Nmax), and there was a lower seedling mortality with (2) wet days than with only one wet day. Evidently, the seedlings were better able to survive the dry period.

The relative seedling mortality of the species which died during the dry period is presented as a percentage of the initial number (Nmax) of seedlings (*Table 3*).

Regarding all water sequences, *Juncus rigidus* had the highest seedling mortality rates with (3) days initial wet period (Experiment No. 2), followed by *Aeluropus brevifolius* at days (2-5) (in experiment No. 1). Across all species, there were more mortality of seedlings with the (1-5) watering sequence, while (2 - 2) watering sequence had the lowest values of dead seedlings. In all experiments, there were significant differences in seedling mortality between species and water sequences (P † 0.05).

This study showed that *Juncus rigidus* have slow seedling emergence characteristics, requiring at least (2) wet days. Most of the plants resulted from seedlings which survived short wet period, *Aeluropus brevifolius* has similar characteristics to that *Juncus rigidus*. The extra day of water produced more initial seedlings (Nmax), and there was alawer seeding mortiality with (2) wet days than with only (1) wet day. Evidently, the seedlings were better able to survive the dry period. (El-Beheiry 1991) noticed that the number of germinated seeds of *Bassia indica*. Wight reveal a very wide range of tolerance to drought. Its wide amplitude of tolerance with regard to wet-dry water sequences results in a wide ecological distribution. For longer wet sequences, it is clear from the present study that the length of initial wet period did not affect the number of surviving seedlings of *Aeluropus brevifolius and Juncus rigidus* .

A plant species may be better adapted to surviving long drought periods if there is a relatively high number of seeds surviving the first wet-dry watering sequence.

The percent of the final seedling counts which are result of seeds surviving the wet-dry periods is presented in (*Table 4*).

Over (50%) of the final number (N14) of *Juncus rigidus* and *Aeluropus brevifolius* seedlings were from seeds surviving (1-5) wet-dry watering sequences. Conversely less than (5%) of the final *Aeluropus brevifolius* seedlings were from surviving seeds with (3-3) and (3-7) wet-dry watering sequences (See, *table 4*). With regard to the final seedlings, *Aeluropus brevifolius* attained the lowest percent at (3-3) wet-dry sequence (3.6%). There were significant differences among species and water sequences for all experiments. There was no correlation of seedling survival to total water availability or loss.

In all experiments, the minimum number of germinated seeds (Gmin) were significant differences (P † 0.05) among species. Only in

Table (3): Percent of initial seedlings (Nmax.) which died after the application of the dry period of three salt marsh species with six wet-dry watering sequences.

Experiment No.	Water sequences (wet-dry) day	Species			
		Atriplex farinosa	Aeluropus brevifolius	Juncus rigidus	X-
1	2 - 2	0.0	15.8	0.0	5.3b
	2 - 5	22.6	47.3	18.2	29.3a
	X-	11.3b	31.5a	9.1c	
2	3 - 3	2.8	11.3	46.3	20.1ab
	3 - 7	3.8	19.3	40.6	21.2a
	X-	3.3c	15.3b	43.4a	
3	1 - 5	28.7	44.9	36.4	36.6a
	2 - 7	12.9	9.1	17.3	13.1b
	X-	20.8b	27.0a	26.9a	

** Means in a row of (X) for a given period followed by the same letter are not significantly different (P < 0.05).*

Table (4): Percent of final seedling counts of three salt marsh species in relation to six wet-dry watering sequences.

Experiment No.	Water sequences (wet-dry) day	Species			
		Atriplex farinosa	*Aeluropus brevifolius*	*Juncus rigidus*	X-
1	2 - 2	10.1	13.1	29.8	7.7b
	2 - 5	30.3	27.5	30.2	29.3a
	X-	20.2b	20.3b	30.0a	
2	3 - 3	5.4	3.6	15.1	8.0a
	3 - 7	8.9	3.8	6.2	6.3b
	X-	7.2b	5.1c	10.6a	
3	1 - 5	46.8	52.3	60.2	53.1a
	2 - 7	15.8	25.8	5.4	15.7b
	X-	31.3b	39.1a	32.8b	

**Means in a row of (X) for a given period followed by the same letter are not significantly different (P < 0.05).*

experiment (No. 2) there was a significant inter-action between the watering sequences and species (P † 0.05). Ranking the species showed that *Atriplex farinosa* had the largest (Gmin) at (2 - 5), (3 -3) and (1-5) days, followed by *Aeluropus brevifolius*, while *Juncus rigidus* had the lowest value, at 3 - 7 days (in the experiment No. 2) (*Table 5*).

Table (5): The minimum number of germinated seeds (Gmin) of three salt marsh species subjected to six wet-dry watering sequences.

Experiment No.	Water sequences (wet-dry) day	Species			
		Atriplex farinosa	*Aeluropus brevifolius*	*Juncus rigidus*	X-
1	2 - 2	88.2	65.6	51.5	68.4b
	2 - 5	99.3	76.7	54.6	77.9a
	X-	93.8a	71.2b	53.1c	
2	3 - 3	93.1	73.8	68.7	78.8a
	3 - 7	81.1	84.1	53.7	72.7b
	X-	87.1a	78.9b	60.9c	
3	1 - 5	90.4	59.2	44.7	64.8a
	2 - 7	73.5	66.6	44.7	61.6b
	X-	81.9a	62.6b	44.7c	

Means in a row of (X) for a given period followed by the same letter are not significantly different (P < 0.05). Values in a column and a row for a given period followed by the same letter are not significantly different (P < 0.05).

For long-term persistence and natural reseeding of range grasses, it may be desirable to have plants which produce a seed which will not germinate fast, but will remain viable in the soil for long periods, such as the *Eragrostis lehmanniana* and *Eragrostis curvula* var. *conferta* (Frasier *et al.* 1985). The present results indicate that the plants characterized with early seedling establishment like *Atriplex farinosa, Aeluropus brevifolius,* may be desirable for *Juncus rigidus*. This study indicates that with the extra day of water, a more durable seedling is produced. This demonstrates the wide range of response of salt mrash species to the characteristics of the first wet-dry sequences.

The daily plant count data for the (5) different wet - dry water sequances show that the *Atriplex farinosa* and *Aeluropus brevifolius* produced seedlings very rapidly, even with the short water sequences (*Fig. 1*).

The *Aeluropus brevifolius* was slower to germinate, and there was a more pronounced effect the length of the first water period on the initial plant count. Over (70%) of these seedlings succumbed during the dry period after (1), (2), or (3) day wet water sequences and over (50%) died after the (4) and (5) day wet sequences. The results suggest that the response of these species to the first wet-dry sequence may provide an objective method for selecting plant species and planting times for optimum survival at a given location. There was good initial seedling emergence and high seedling mortality during the dry period. Less than (70%) of the viable seeds survived the wet-dry water sequence.

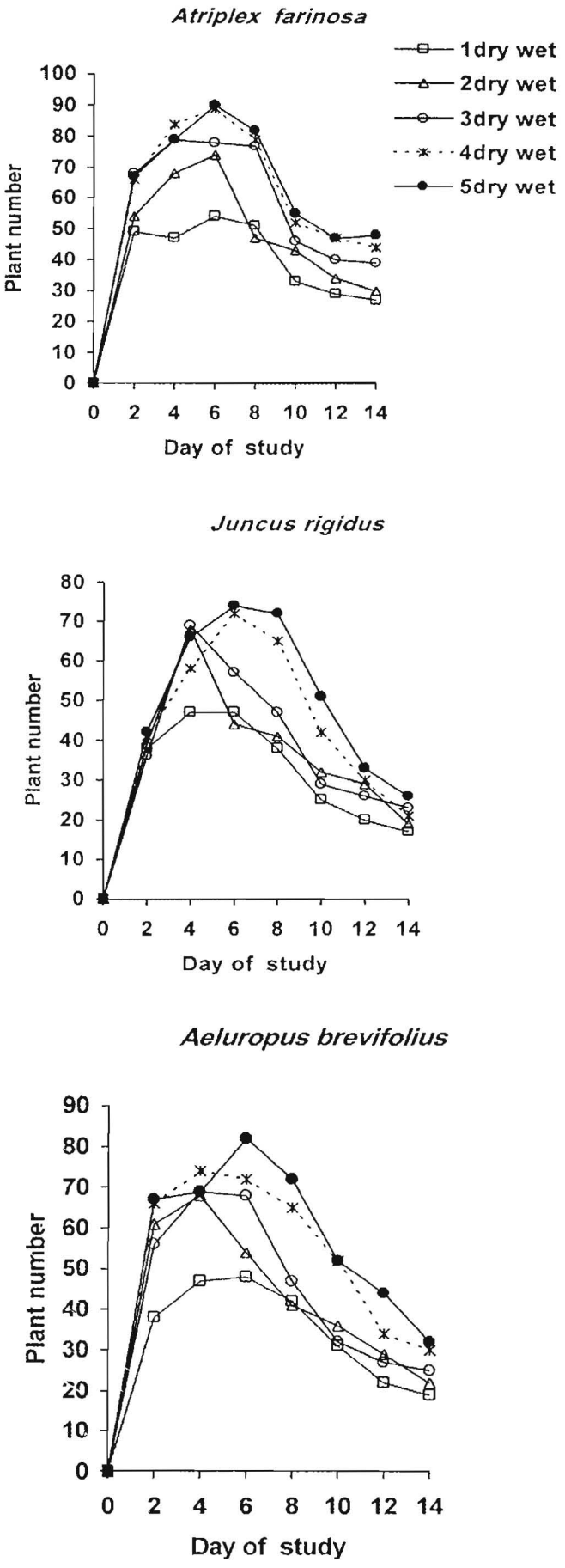

Fig. (1): Daily mean plant count from 100 seeds of *Atriplex farinosa, Juncus rigidus and Aeluropus brevifolius* during different lengths of wet periods each followed with 5 dry days.

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