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CHALLENGES IN DRYLAND AGRICULTURE
—
A GLOBAL PERSPECTIVE

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87 Precipitation Frequency Effects on Seedling Survival

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Introduction

Water is a key factor in the success or failure of achieving plant establishment from seeds. Some guidelines recommend seeding only in areas where the annual precipitation exceeds a predefined amount (Stoddart, 1946). New species releases frequently make reference to adaptability in specific annual rainfall zones (Booth et al., 1980; Stevens et al., 1985). Cox and Jordan (1983) found that the frequency and quantity of precipitation at the time of seeding were much more critical to seedling establishment than the total annual precipitation. With respect to water, there are two periods of major importance in seedling establishment: the initial wet period when seeds germinate, and the subsequent dry period. In suitable wet periods, seeds will germinate and develop seedlings to a physiological stage capable of surviving the following dry period. Frequently the seeds germinate but there is insufficient moisture for full seedling development. To achieve success in seedling establishment two conditions must be satisfied. First, species selected must be capable of producing a viable seedling in the wet-dry soil moisture regime that occurs in the field. Second, seeding must be timed to utilize the maximum probability of adequate soil water for seed germination, seedling growth, and root extension sufficient to maintain the plant through the next dry period.

Frasier et al. (1984) described a technique of combining the probabilities of seedling survival in various wet-dry watering sequences with the probabilistic aspects of precipitation occurrence. This paper is a continuation of that study with emphasis on the effect of the timing and duration of the first dry period following seed germination. Germinated seed and seedling survival data of eight plant species with nine wet-dry watering sequences are compared to the occurrence probability of various lengths of dry periods at four locations.

Procedures

Seedling Survival Studies

Plant species were selected to provide a range of establishment and survival characteristics; sideoats grama (*Bouteloua curtipendula*), blue grama (*B. gracilis*), cane beardgrass (*Bothrichloa barbinodes*), Lehmann lovegrass (*Eragrostis lehmanniana*), plains lovegrass (*E. intermedia*), crested wheatgrass (*Agropyron cristatum*), mesquite (*Prosopis juliflora*), and cheatgrass (*Bromus tectorum*). Greenhouse studies were conducted using the procedure of Frasier et al. (1984). Tapered plastic cones, 6.35-cm diameter by 24.0-cm long were filled with 660 g of dry 60-mesh silica sand. Ten seeds were placed on the dry surface of each cone and covered with a 3-mm layer of dry sand. Two cones of each species were prepared for each wet-dry watering sequence.

Dry periods of 5 days, 7 days, and extended (x) (sufficient time to kill all seedlings and germinated seeds) were used in combination with wet periods of 2, 3, and 5 days. All cones were initially wetted to approximate field capacity, then watered daily in the predetermined wet-dry-wet watering sequence with an overhead reciprocating spray system. Cones in a dry period were covered during sprinkling with a removeable sheetmetal roof. Cones in the wet period were sprinkled daily with sufficient water to bring the average moisture content to the original field capacity. Following the dry period, the cones were wetted daily for a total study length of 14 and 16 days for the 5 and 7 days dry sequences, respectively. Cones in the extended dry sequences were wetted for 6 days following the dry period. The experiments were repeated three times.

The number of live plants in each pair of cones were summed and recorded daily. Total seed germination percentages (pure live seed) were defined as the maximum number of seedlings that emerged in the initial wet period plus the number of seedlings produced in the final wet period from seeds which did not germinate in the initial wet period. No attempt was made to evaluate differences among species or watering sequences. Data analysis consisted of computing daily means of the seedling counts and calculating the percentages of germinated seeds and surviving seedlings.

Probability of a Dry Interval

The probability of various dry interval lengths was developed using a first-order, non-homogeneous Markov chain to model the occurrence of daily rainfall (Woolhiser and Roldan, 1986). The occurrence process is described by the sequence X_t, $t = 1, 2, \ldots$ where $X_t = 1$ if the day is wet and $X_t = 0$ if the day is dry. The model utilizes the parameters $P_{00}(n)$, the probability of a dry day on day (n) given that day (n-1) was dry, and $P_{10}(n)$, the probability of a dry day given that day (n-1) was wet. Fourier series were used to describe the daily variation in P_{00} and P_{10}. It can be shown, that the probability of a dry interval of at least (k) days beginning on day (n) is:

$$P[L_0 \geq k] = 1 - \sum_{j=1}^{k-1} [1-P_{00}(n+j)] \prod_{i=1}^{j=1} P_{00}(n+i); \; k=2,3,... \qquad [1]$$

By definition when j = 1, II = 1 (Buishard, 1977).

Markov chain parameter values were calculated for four locations, Tombstone, AZ, Reynolds, ID, Hastings, NE, and Cherokee, OK, using a threshold of 0.254 mm (0.01 inches). Values for the means, amplitudes, and phase angles were obtained by maximum likelihood techniques using the AQUA4 computer program (Woolhiser and Roldan, 1986). The parameters were then used in equation (1) to obtain a yearly plot of the occurrence probabilities of dry interval lengths greater than or equal to 3, 5, 7, or 14 days.

Results

Seedling Survival Studies

Some notable results from the greenhouse studies were: (1) Cheatgrass, sideoats grama, and mesquite seedlings began emerging within 24 hours of initial wetting; (2) cane beardgrass and Lehmann lovegrass seedlings began emerging with the 3 days wet watering sequences; and (3) five wet days were required for initial emergence of plains lovegrass and crested wheatgrass seedlings (Figure 1).

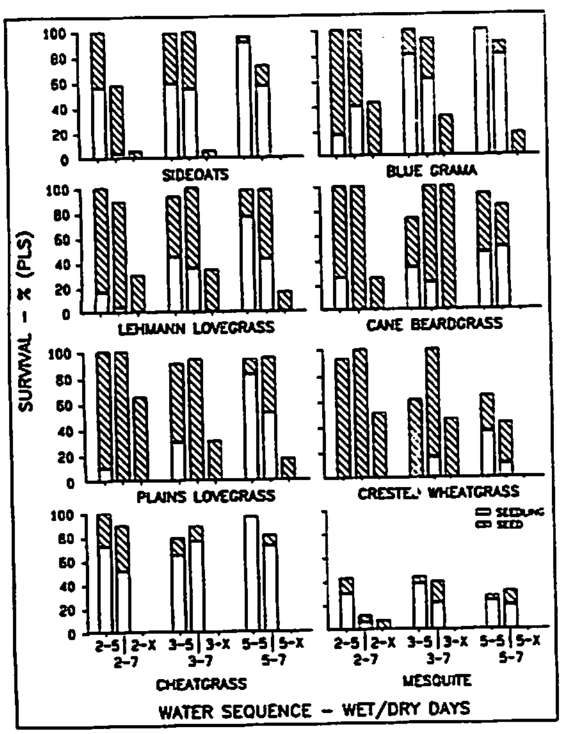

Figure 1. Survival of seeds and seedlings of 8 plant species for 9 wet-dry watering sequences.

With the exception of sideoats grama and mesquite at 2 wet days and crested wheat and cane beardgrass at 3 wet days, differences in the numbers of seeds and seedlings surviving dry periods of 5 to 7 days were probably not significant (Fig. 1). With all species, the longer the initial wet period, the greater the number of emerged seedlings which survived the 5- or 7-day dry periods. There were fewer surviving viable seeds following the extended dry periods than with the 5- or 7-day dry periods. This indicates that many seeds initiate the germination process, even with only 2 wet days, and are capable of surviving dry periods up to 7 days in length. These germinated seeds will die with some undetermined longer length of dry period.

Probability of the Lengths of Dry Intervals

The four locations used to determine the probabilities of dry interval lengths were selected to provide a range of conditions. Tombstone, AZ, has a dry period in April through June followed by the wet "monsoon" season in July through September. Reynolds, ID, has a dry period in July through August with precipitation occurring in the winter, spring, and fall periods. Hastings, NE, and Cherokee, OK, are characterized by a spring-summer precipitation period. The computed exceedence probabilities of dry interval lengths for each site are illustrated in Figure 2 and show the differences in dry patterns that can occur. Tombstone, AZ, has a dramatic shift in the probabilities of dry period occurrence from the late spring to midsummer period. Reynolds, ID, has a high probability of a dry period in the summer months while Cherokee, OK, and Hastings, NE, have low dry period probabilities during the summer. Other locations may have still different patterns.

Discussion

Because the distribution of the length of dry period following a wet period is only one factor in the complex process of germination and seedling establishment, it provides only an approximate indication of the best time to seed. With the exception of mesquite and crested wheat, all species studied had an 80% probability of surviving dry periods of 5 to 7 days as seedlings and/or germinated seeds. Therefore, these species should be seeded when other factors are favorable and there is a minimum probability of dry periods greater than 5 to 7 days. If we select the period when the probability of a dry period of 5 days or more is smaller than 50%, the proper time to seed is: July-August in Tombstone, AZ; spring-summer in Hastings, NE, and Cherokee, OK;, and winter, spring, or fall for Reynolds, ID (the cross-sectioned area, Fig. 2). Additional factors not included in this discussion would be: initial wet periods of sufficient duration to germinate the seeds, rate of soil water loss by evapotranspiration, and soil temperatures conducive to seed germination. The complete analysis of combining

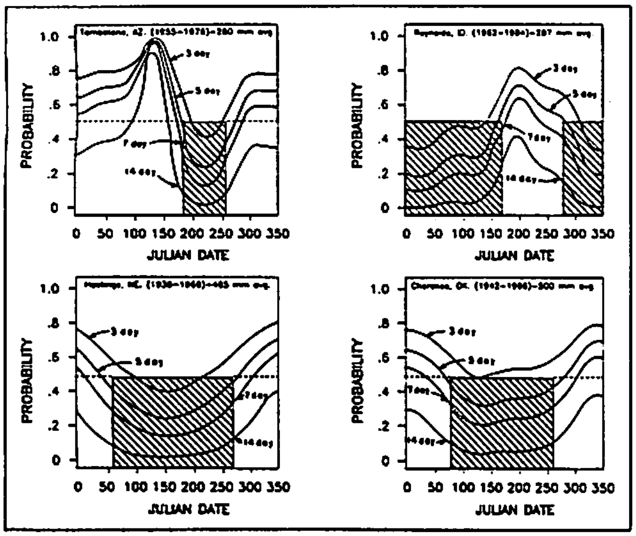

Figure 2. Exceedence probabilities of dry interval lengths of 3, 5, 7 and 14 days for 4 locations.

seedling survival characteristics with probabilities of precipitation occurrence must also include different threshold levels of precipitation.

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