The seedling stage is a critical period in the establishment of perennial grasses during which many plants succumb to the rigors of the environment. Excellent seedling stands are often partially or completely killed by temperature extremes and drought, sometimes necessitating replanting. A more thorough knowledge of seedling emergence and survival characteristics of specific grasses as related to environmental factors will contribute toward more successful plantings. This study was undertaken to learn more fully the environmental effects of frost and summer drought on seedlings of 16 prominent grasses used for seeding in the Intermountain Region. Although the study was conducted in the sagebrush and mountain brush zones of central Utah, the findings will have application, at least in part, to other areas where these grasses are used.

Numerous experiments have been conducted on cereal grains with respect to frost and winter hardiness as well as drought resistance, but studies with perennial grass seedlings are more limited. Most such studies with grass seedlings have been under artificial conditions. Rogler (12) found that seedling survival of cool temperature grasses was much higher than that of warm temperature species when artificially frozen at various temperatures. Arakeri and Schmid (2) found that grasses were susceptible to freezing during the early stages of development prior to emergence, but that they again became resistant after emerging and when in the one-leaf stage. Some of the grasses became susceptible to freezing again after they attained the 2- to 3-leaf stage. Field studies by Plummer and Fenley (10) in the subalpine zone of central Utah showed that very high seedling mortality resulted from winterkilling.

In studying soil drought resistance of grass seedlings, McAlister (7) found that age of seedlings had an important effect upon survival. There were no significant differences in survival between strains of slender wheatgrass and smooth brome when seedlings were 1 month old, but differential survival between strains within either species was observed when seedlings were 6 weeks to 2 months old at the time drought treatment began. Differences in soil fertility and the hardening treatment prior to drought had no significant effect upon seedling survival. Plummer (9), Bailey (3), and Cook (6) have shown that drought resistance increases with root development in grass seedlings.

**Description of Planting Sites**

The two sites used for this study are located (a) in the sagebrush zone in Sanpete Valley near Ephraim, Utah at an elevation of 5,500 feet; and (b) in the mountain brush zone of Circle Canyon at an elevation of 7,200 feet. Average precipitation is around 15 inches at the mountain brush zone and approximately 60% of which falls as snow during the winter, under 11 inches at the valley site, approximately 90% as snow. Average mean annual temperatures are 46.1°F for the sagebrush zone and 46.1°F for the sagebrush zone of central Utah, with respect to frost and winter hardiness as well as drought resistance. Studies with perennial grass seedlings are more limited. Most such studies with grass seedlings have been under artificial conditions. Rogler (12) found that seedling survival of cool temperature grasses was much higher than that of warm temperature species when artificially frozen at various temperatures. Arakeri and Schmid (2) found that grasses were susceptible to freezing during the early stages of development prior to emergence, but that they again became resistant after emerging and when in the one-leaf stage. Some of the grasses became susceptible to freezing again after they attained the 2- to 3-leaf stage. Field studies by Plummer and Fenley (10) in the subalpine zone of central Utah showed that very high seedling mortality resulted from winterkilling.

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Natural vegetation in the mountain brush zone consists of solid patches of gambel oak (Quercus gambelii) with serviceberry (Amelanchier alnifolia), bitterbrush (Artemisia tridentata), big sagebrush (Artemisia tridentata), and various meadow species. Natural vegetation in the sagebrush zone consists of grass species as big sagebrush (Artemisia tridentata), bluebunch wheatgrass (Agropyron smithii), and western wheatgrass (Agropyron spicatum), interspersed with serviceberry (Amelanchier alnifolia), bitterbrush (Purshia tridentata), and annual weeds.

Natural vegetation in the mountain brush zone consists of grass species as well. As a result of overgrazing and cultivation, cheatgrass (Bromus tectorum) now occurs underneath the sagebrush and in openings and is the most abundant species in the zone. Such grass species as big sagebrush, western wheatgrass, and Indian ricegrass (Oryzopsis hymenoides) occur in limited amounts throughout the zone.

The soils are chiefly of limestone origin — a silt loam on the oakbrash site and a loam on the sagebrush site. Very little dispersion of the clay was within the range for soils in central Utah. Soils to the 12-inch depth are very high in lime, available phosphorus, and nitrate-nitrogen, indicating good fertility, especially in the mountain brush zone. However, better fertility exists at the upper site, with matter content there being twice that of the lower site.

**Methods**

Natural vegetation on the upper area was burned off in the fall of 1946, and weeds were kept out during the summer prior to planting in the fall of 1947. At the lower area, a stand of Russian thistle (Salsola kali var. tridentata) was eradicated before seeding. Plantings were made in early fall, late fall, and spring in a randomized split-block design with four replications at each site. Two hundred seeds of each grass were planted in rows 10 feet long, 1 foot apart. Seeds were dropped into small furrows then covered with ½ to ¾ inch of soil. The soil was watered before planting, leaving a slight depression along each row. Seedlings were weeded during the study period to make conditions as nearly as possible.

Early fall plantings were made October 10 and 15 at the mountain site and October 15 and 16 at the valley site. Late fall plantings were made December 4 and December 16 at the mountain and valley sites, respectively. These plantings were delayed because of the amount of snow on the ground. In fact at the lower site

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4 Contribution from the Intermountain Forest and Range Experiment Station, Forest Service, U. S. D. A., Ogden, Utah. Received for publication June 30, 1950.

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