SOME FACTORS AFFECTING GERMINATION, EMERGENCE, AND EARLY GROWTH OF THREE RANGE GRASSES[1]

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ABSTRACT

Factors affecting germination, emergence, and early growth of *Festuca scabrella*, *Danthonia parryi*, and *Bromus pumpellianus* were studied in the germinator or greenhouse. Germination of *D. parryi* was not affected differentially at temperatures ranging from 55°F. to 85°F. *F. scabrella* germinated best at 65°F. and *B. pumpellianus* at 75° to 85°F. Percentage germination of *F. scabrella* was inhibited by a wet-cold treatment and by a solution prepared from partially decomposed litter. Shallow seeding was found to offer the best opportunity for seedling establishment. Fewest seedlings survived where competition was greatest, i.e. when seeds were broadcast on the surface of a rapidly-growing, established sod. This treatment produced the least vigorous seedlings as measured by tiller or rhizome numbers, dry matter yields, and root and leaf lengths.

In a depth-of-litter study involving *F. scabrella*, as the depth of litter increased, the percentage emergence of seedlings decreased. Seedlings continued to emerge for an 85-day period from all except shallow (½-inch) litter depths of seeding.

Six square-foot sods obtained in mid-June, 1958, from *Festuca* prairie in excellent condition were dissected in the laboratory. Numbers and locations of seedlings were recorded and showed that the same trends existed on the prairie as were detected in the greenhouse experiments. The cumulative results of the studies suggested that seed and seedling mortality in the grasses studied was of considerable magnitude.

INTRODUCTION

There are apparently two contrasting views on the importance of seed set and subsequent dispersal of ripe seed in the maintenance of native grass stands. For example, it has become a tenet of range management that the production of an occasional large, viable seed crop is necessary in order to maintain a native grass stand in a strong, vigorous condition. This has been pointed out by Sampson (13) and Stoddart and Smith (15), particularly in relation to their discussions of various types of rotational grazing systems. Ellison (4) has suggested that the presence of seedlings may be used to determine the recent history of a species and may provide clues as to the maintenance of that species in a stand. In contrast to this view, Robertson and Pearse (11) have discussed the "closed community" concept which holds that established stands of vegetation are not readily invaded and that mass invasion, without opening of the community by external means, is nearly impossible. Blake (1) has stated that "the prairie is a closed formation" and points out that, on the prairie, seedlings find establishment difficult. Simpson and Moore (14) have reported that, while the possibilities of indigenous species for use in depleted rangelands have been suggested frequently, the general experience has been that few plants, regardless of species, establish from broadcast seedings. In a study of *Dianthus prolifer* and *Verbascum thapsus*, Salisbury (12) noted seedling mortality of from 95 to 99 per cent and states that mortality in plants is almost entirely a feature of the juvenile stage. He points out that, on theoretical grounds and over a long period of time, for every parent plant that perishes only one offspring will survive.

[1]Contribution from the Forage Crops Section.

Germination and early growth of grasses have been studied by numerous investigators (1, 4, 10, 14). Glendening (5) found that litter enhanced the chances of new plants to establish themselves through natural reproduction from seeds. Hopkins (6) also has discussed the importance of natural mulch, particularly in relation to soil temperatures and soil moisture content.

In an effort to reconcile the contrasting views mentioned above, a series of experiments were started in the greenhouse in 1957. Purposes of the study were to determine the viability of seed of three native grasses by germination tests; to follow the early growth of the seedlings produced under a variety of conditions comparable to those found in the field; to determine the effects of various depths of litter on emergence and early development; and to relate the results of greenhouse experiments to field conditions.

METHODS

Three native grasses, *Festuca scabrella* Torr., *Danthonia parryi* Scribn., and *Bromus pumpellianus* Scribn., were selected for the study. The two former species are co-dominants in the *Festuca-Danthonia* faciation of the *Festuca scabrella* association (3, 8). The latter is a minor species within the association but may be locally abundant, particularly on disturbed sites. Seed of each species was collected during August and September at the Range Experiment Substation, Stavely, located in the Porcupine Hills of southwestern Alberta. Seeds were stored at 45°F. and were utilized in germinator and greenhouse tests within 3 to 4 months of the collection date. Well-filled, hard seeds were selected for the study.

The results of a number of germinator and greenhouse experiments and some field observations are reported herein. These fall into four general groups as follows:

1. Germinator Tests

A series of germinator tests were conducted with *F. scabrella, D parryi,* and *B. pumpellianus.* These were conducted in a Manglesdorf germinator at temperatures of 55°F., 65°F., 75°F., and 85°F. The effects of several seed treatments on the germination of *F. scabrella* and *D. parryi* were studied. One hundred seeds of the species concerned were placed in a folded paper towel and kept moist by daily waterings. Counts were made at daily intervals for a 3-week period following initial germination.

2. Germination and Early Growth under Various Conditions

Eight-inch unglazed earthenware pots filled with a 60:40 mixture of loam and sand were used in all treatments. This pot size was selected because observations indicated that 100 seeds scattered on the soil surface gave a density of seeding comparable to that obtained as a result of natural seed dissemination in a better-than-average seed year. In an attempt to simulate some of the conditions that would be encountered in the field, the following treatments were devised:

a) Unclipped sods obtained in early November from range in excellent condition were trimmed to an 8-inch diameter and 4 inches deep and transplanted into pots. The sods were allowed to become established, after which 100 seeds were scattered on the surface. In each experiment, sods and seeds were of the same species.

b) One hundred seeds were scattered on top of a 2-inch layer of litter that had previously been placed on the soil surface.
c) One hundred seeds were scattered on the soil surface and were covered by a 2-inch layer of litter.
d) One hundred seeds were broadcast on the soil surface.
e) One hundred seeds were sown ¼-inch deep.

3. Effects of Various Depths of Litter on Emergence and Early Development

The effects of various depths of litter on a single species, *Festuca scabrella*, were studied. Eight-inch earthenware pots and a 60:40 mixture of loam and sand were used. Treatments were as follows:

One hundred seeds were broadcast on the soil surface and were
1) covered by ½ inch of litter;
2) covered by 1 inch of litter;
3) covered by 1½ inches of litter.

One hundred seeds were broadcast on litter layers of
1) ½ inch and were covered by ½ inch of litter;
2) 1 inch and were covered by 1 inch of litter;
3) 1½ inches and were covered by 1½ inches of litter.

4. Field Observations

In mid-June, 1958, six square-foot sods were obtained from native prairie in excellent condition that was dominated by *F. scabrella*. These sods were dissected under magnification. Numbers and location of *F. scabrella* seedlings, both dead and living, were recorded and ungerminated seeds of the species were collected.

Plant litter refers to the dead, but undecomposed, vegetative material present on the surface of the soil. It may be separate from, or attached to, the parent plant. In this study, the litter used in any experiment was obtained from sites dominated by the grass species concerned. The material was steam-sterilized for 6 hours prior to use to ensure freedom from seeds.

In all germinator or greenhouse experiments, treatments were replicated four or six times in a randomized block. A colour code, utilizing plastic "Party-Pics", was used in sections 2 and 3 above, to identify emerging seedlings individually at 10-day intervals during the 3-month growth period. Greenhouse temperatures varied from a high of 75°F. during the day to 55°F. at night. A day length of 16 hours was maintained throughout. All treatments received light, frequent waterings during the course of the experiment.

RESULTS

Germinator Tests

The effects of temperature on the percentage germination of *F. scabrella*, *D. parryi*, and *B. pumpellianus* are shown in Table 1. The optimum germination temperature of *F. scabrella* appeared to be 65°F. although seed of the species germinated readily at 55°F. and 75°F. Germination percentages of *D. parryi* were generally low and did not appear to be affected differentially at the temperatures used in the study. *B. pumpellianus* germinated best at temperatures of 75° and 85°F. There

TABLE 1.—PERCENTAGE GERMINATION, AND DAYS TO INITIAL GERMINATION, OF THREE RANGE GRASSES AT FOUR TEMPERATURES (AVERAGE OF 4 REPLICATES)

	Festuca scabrella		*Danthonia parryi*		*Bromus pumpellianus*	
Temperature	% germ	No. days	% germ	No. days	% germ	No. days
55° F.	69	7.0	51	10.2	3	9.5
65° F.	80	5.0	52	4.2	50	7.0
75° F.	71	5.5	46	5.0	89	4.0
85° F.	14	6.5	52	2.7	90	7.0
L.S.D. at 5% level	11		4		5	
L.S.D. at 1% level	16		N.S.		7	

TABLE 2.—EFFECT OF THREE SEED TREATMENTS ON THE PERCENTAGE GERMINATION OF *Festuca scabrella* AND *Danthonia parryi* AT TEMPERATURES OF 55° F.

Treatment	*Festuca scabrella*	*Danthonia parryi*
Untreated	76	51
5° F. for 24 hours	73	44
Soaked 2 hours, 5° F. for 24 hours	41	39
L.S.D. at 1% level	19	5

were differences between species in the time required for initial germination, *F. scabrella* germinating most rapidly at 65°F., *B. pumpellianus* at 75°F. and *D. parryi* at 85°F.

The effects of several seed treatments on the germination of *F. scabrella* and *D. parryi* were studied. Data obtained are shown in Table 2. At a temperature of 55°F. the percentage germination of *F. scabrella* and *D. parryi* were significantly ($P < 0.01$) reduced as the result of a treatment which involved soaking the seed in water for 2 hours and then holding it at 5°F. for 24 hours prior to being placed in the germinator. Percentage germination of *D. parryi* was also reduced ($P < 0.01$) by holding the dry seed at 5°F. for 24 hours prior to being placed in the germinator. These results were of interest since moderate days with melting snow, followed by freezing night-time temperatures, are frequently encountered in the Porcupine Hills during the spring months. Such conditions might be expected to significantly affect the germination of both species on rangeland.

Germination and Early Growth under Various Conditions

Perhaps the most interesting result of the study was that some seeds germinated, and the resulting seedlings grew and persisted throughout the study period, under all treatments. These treatments ranged from seeds broadcast, seeds sown ¼-inch deep, seeds broadcast on the surface of a 2-inch litter layer, seeds broadcast and covered by a 2-inch litter layer, to seeds broadcast on the surface of a rapidly-growing, established sod. The latter is illustrated in Figure 1 since the treatment seemed to provide the most difficult micro-environment for seedling establishment. An average

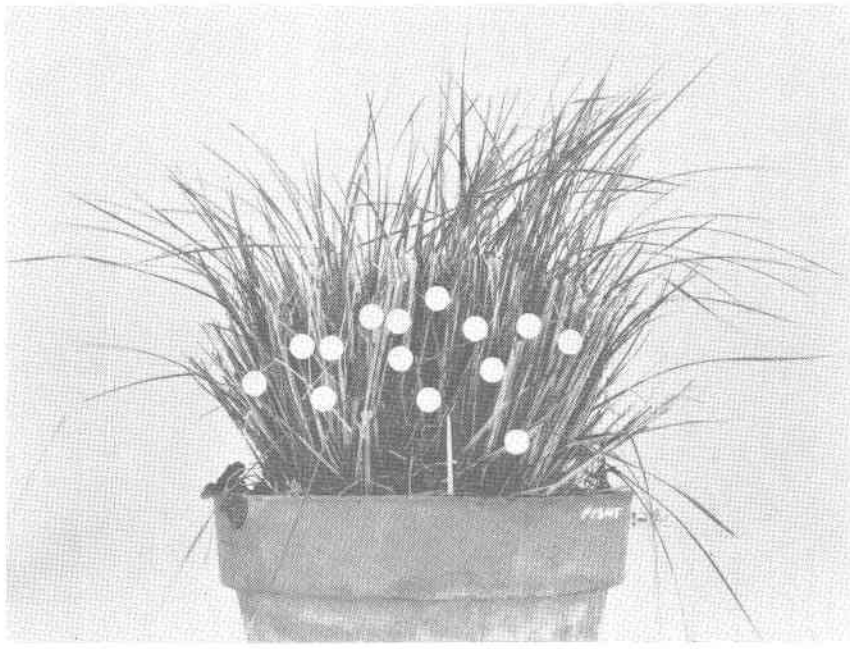

FIGURE 1. Mature plants of *Festuca scabrella* on which the germination and growth positions of several seedlings are indicated.

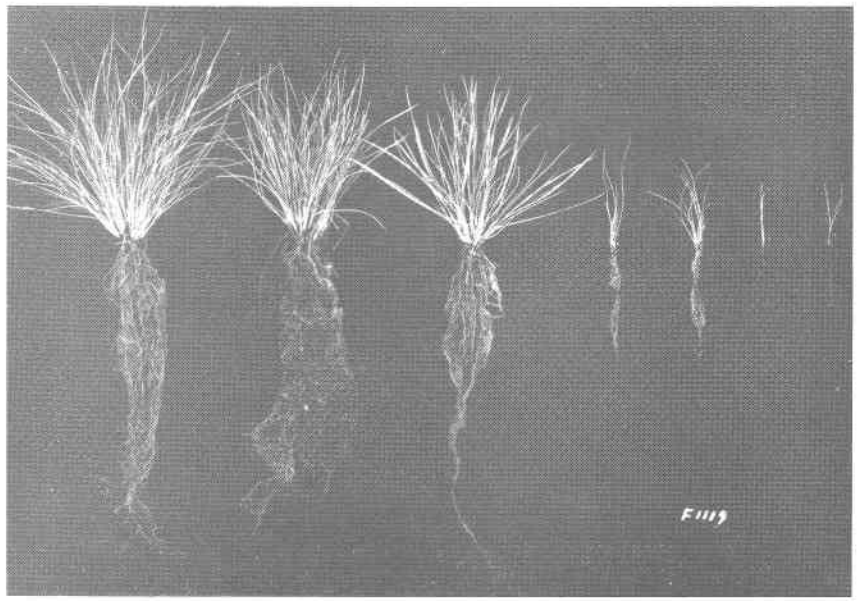

FIGURE 2. Three-months-old seedlings of *Festuca scabrella* grown under the following conditions: (*left to right*) broadcast on a 2-inch layer of litter; sown ¼ inch deep; broadcast on soil surface; two seedlings from interspace surrounding mature plant; two seedlings from within a mature plant.

TABLE 3.—PERCENTAGE GERMINATION OF THREE RANGE GRASSES AND PERCENTAGE SURVIVAL AFTER A 3-MONTH GROWING SEASON UNDER VARIOUS CONDITIONS (AVERAGE OF 6 REPLICATES)

Treatment	*Festuca scabrella*		*Danthonia parryi*		*Bromus pumpellianus*	
	% germination	% survival	% germination	% survival	% germination	% survival
Broadcast on sod surface:						
Within plants	43.8	24.7	17.9	6.7	26.9	21.2
Interspace	26.4	23.3	11.2	7.5	17.0	16.8
Total for treatment	70.2	48.0	29.1	14.2	43.9	38.0
Broadcast, surface of 2 inches litter	74.7	70.7	35.4	25.2	44.0	42.8
Broadcast, covered by 2 inches litter	[1]	0	[1]	0	50.0	46.8
Broadcast on soil surface	77.0	73.2	38.5	17.0	39.0	38.2
Sown ½-inch deep	80.7	78.2	50.5	44.5	86.4	85.2

[1]Seeds germinated but no seedlings emerged

TABLE 4.—SEEDLING VIGOUR OF THREE RANGE GRASSES GROWN FOR A 3-MONTH PERIOD UNDER VARIOUS CONDITIONS AS SHOWN BY AVERAGE ROOT AND LEAF LENGTH, NUMBER OF TILLERS OR RHIZOMES, AND DRY MATTER YIELDS OF ROOT-GROWTH AND TOP-GROWTH (AVERAGE OF 6 REPLICATES)

Treatment	*Festuca scabrella*			*Danthonia parryi*			*Bromus pumpellianus*			
	Av. length in inches	Tillers per seedling	DM in gm. per pot	Av. length in inches	Tillers per seedling	DM in gm. per pot	Av. length in inches	Rhizomes per seedling		DM in gm. per pot
	Root Leaf		Root Leaf	Root Leaf		Root Leaf	Root Leaf	Number	Length in inches	Root Leaf
Broadcast on sod surface:										
Within plants	1.15 2.17	0.4	0.10 0.10	1.38 1.56	1.0	Trace0.10	3.24 5.56	3.2	2.15	1.95 3.93
Interspace	2.96 2.92	3.3	1.95 0.78	2.04 2.56	1.2	0.01 0.05	4.20 5.75	3.4	1.70	1.60 4.07
Total for treatment			2.05 0.88			0.01 0.15				3.55 8.00
Broadcast, surface of 2 inches litter	4.42 4.58	22.7	5.95 4.13	5.03 4.33	5.7	0.36 2.80	9.33 12.92	7.4	8.72	13.25 9.22
Broadcast, covered by 2 inches litter	— —	—	— —	— —	—	— —	9.25 12.83	4.4	8.39	13.24 9.89
Broadcast on soil surface	5.08 3.71	12.6	3.68 1.94	7.55 5.43	13.5	2.62 5.72	7.25 8.58	6.9	6.78	7.03 7.11
Sown ¼-inch deep	4.83 3.38	6.9	6.40 2.52	6.59 5.54	6.7	2.30 8.43	7.50 10.33	3.7	4.66	13.14 14.82

of 43.8 seeds germinated, and 24.7 seedlings survived for a 3-month study period, within the *F. scabrella* plant shown. The relative positions occupied by some of these seedlings are indicated on the figure. An average of 23.3 seedlings developed in the interspace surrounding the mature plant. These locations are referred to as "Within plants" and "Interspace" in Tables 3, 4, and 6.

At least one investigator has noted that the crowns of plants provide conditions suitable for seedling establishment. Campbell (2), discussing the invasion, by crested wheatgrass (*Agropyron cristatum*), of a stand of intermediate wheatgrass (*Agropyron intermedium*) that had been gradually winter-killed, states: "As the stand of intermediate wheatgrass decreased, the field was invaded by crested wheatgrass from nearby seed sources. The interesting point about the invasion was that the crested wheatgrass developed in the dead or dying crowns of the intermediate wheatgrass. This invasion and establishment preserved the pattern, so that the field had the appearance of a crested wheatgrass field seeded in 12-inch rows".

Table 3 shows the percentage germination and percentage survival after a 3-month growth period, of the three grasses as influenced by a variety of conditions. As previously mentioned, some seeds germinated and, with two exceptions, some seedlings persisted, throughout. These exceptions were the seeds of *F. scabrella* and *D. parryi* that had been broadcast on the soil surface and covered by a 2-inch depth of litter. At the end of the study period, as no seedlings had emerged, the then partially decomposed litter layers were removed from the soil and the surfaces were examined for evidence of seeds. From 11 to 36 identifiable seeds were recovered from each pot; all were partially to nearly completely decomposed; many had produced a primary root up to ¾ of an inch long and an epicotyl up to ¼ of an inch long. Since some factor in addition to depth of substrata had seemingly prevented emergence, a leachate was prepared as suggested by Nielsen *et al.* (9) using the partially decomposed litter. This material and distilled water were used in a paired plot germination test with seed of *F. scabrella.* Average germinations obtained were 63 per cent where the leachate solution was used and 80 per cent where the distilled water was used. These differences were significant ($P < 0.01$) and suggest that increasing depths of litter exert an inhibiting effect on germination of the species as well as offering a physical barrier to the emerging seedling.

Seedling mortality between germination and the 3-months-old seedling stage varied with the treatment and with the species. Least seedling mortality was shown by *B. pumpellianus* and varied from 78 per cent survival of developed seedlings "Within plants" to 98 per cent survival when sown ¼-inch deep. Highest seedling mortality was exhibited by *D. parryi*, only 37 per cent of the developed seedlings being able to survive "Within plants", 44 per cent where broadcast on the soil surface, to a high of 88 per cent under shallow seeding. Survival of *F. scabrella* seedlings was equal to that of *B. pumpellianus* except that only 56 per cent of the seedlings which developed survived "within plants". As these figures represent sur-

TABLE 5.--PERCENTAGE EMERGENCE, PERCENTAGE SURVIVAL, VIGOUR MEASUREMENTS, AND DAYS TO EMERGENCE OF *Festuca scabrella* SEEDLINGS GROWN UNDER VARIOUS CONDITIONS
(AVERAGE OF 4 REPLICATES)

Treatment	Percentage emergence	Percentage[1] survival	Average length of leaf (in.)	Tillers per seedling	Average days to emergence
Seeds broadcast on soil surface and:—					
—covered by ½ inch of litter	60.0	46.0	3.9	10.2	9.0
—covered by 1 inch of litter	34.0	26.0	4.7	9.0	11.0
—covered by 1½ inches of litter	16.2	8.7	4.2	9.2	13.5
Seeds broadcast on litter layer of:—					
—½ inch, covered by ½ inch of litter	59.2	56.0	3.1	6.0	15.0
—1 inch, covered by 1 inch of litter	25.7	18.2	3.5	3.2	17.5
—1½ inches, covered by 1½ inches of litter	9.7	6.0	1.4	0.2	41.7

[1]Refers to percentage emerged plants surviving

vival under presumably optimum growing conditions, it is likely that seedling mortality on rangeland would be considerably greater.

Data are presented in Table 4 to show the relative vigour exhibited by seedlings of the three grasses grown under a variety of conditions. Differences in vigour of *F. scabrella* seedlings are clearly shown in Figure 2. The least vigorous seedlings were those subjected to the greatest degree of competition, i.e., broadcast on the surface of an established sod. This was reflected in shorter root and top-growth, fewer tillers or rhizomes, and a lower yield of dry matter per treatment. Highest dry matter yields were produced as a result of shallow seeding, since this treatment had resulted in the development of more seedlings than any other. Seedlings produced as a result of broadcasting on the soil surface were well developed as was shown by tiller or rhizome numbers. During the growth period, however, it was noted that seedlings experienced difficulty in rooting under this treatment. Many were anchored by only a single primary root for a considerable period of time and tended to grow in a prostrate position. About 30 per cent of the seedlings produced by all species exhibited this characteristic. In the pot study, rooting gradually took place and vigorous plants resulted. It is doubtful if this would have occurred on rangeland as the poorly anchored seedlings would have been highly susceptible to the desiccating effects of winds.

The largest plants produced by *F. scabrella* and *B. pumpellianus* were those grown on top of a 2-inch litter layer. As previously mentioned, there were indications that this material exerted an inhibiting effect on germination of *F. scabrella.* After seedling establishment, the effects of litter appeared beneficial. Plants produced under this treatment were conspicuous because of their rich green colour. As this appeared to be due to additional nitrogen, obtained from the decomposing litter, a series of nitrogen determinations were made on the partially decomposed litter and on samples of the original material. Nitrogen content of the partly decomposed litter was 1.10 per cent and that of the undecomposed material was 1.72 per cent. These differences were significant ($P < 0.05$). Iritani and Arnold (7) have shown that a portion of the nitrogen contained in vegetable crop residues may be released and utilized by the growing plant.

Effects of Various Depths of Litter on Emergence and Early Development

Data are presented in Table 5 showing the percentage emergence, percentage survival, and average number of days before emergence, of *F. scabrella* seedlings grown under and between various depths of litter. Two measurements of seedling vigour are included. As depth of litter increased, the percentage emergence decreased. Emergence was considerably delayed with increasing depths of litter, 41.7 days being required for seedlings to emerge from the treatment which involved seeds broadcast on a 1½-inch litter layer and covered by a further 1½ inches of litter. The roots of only a few seedlings had penetrated to the soil surface at the end of the 3-month study period under this treatment. Seedlings continued to emerge for an 85-day period in all treatments except those involving

TABLE 6.—NUMBERS AND LOCATION OF *Festuca scabrella* SEEDLINGS DISSECTED FROM SIX SQUARE-FOOT SODS OBTAINED FROM PRAIRIE IN EXCELLENT CONDITION, JUNE, 1958

	Dead		Alive	
Sod number	Top of 1-inch litter in interspaces	Within plants	Top of 1-inch litter in interspaces	Within plants
1	21	6	0	1
2	0	5	1	0
3	15	8	3	0
4	4	7	1	0
5	14	13	2	3
6	11	7	1	1
Average	10.8	7.7	1.3	0.8

seeds covered by a half-inch of litter. Percentage survival of emerged seedlings was best at shallow litter depths and poorest in the treatment where seeds had been scattered on the soil surface and covered by 1½ inches of litter. Only 53 per cent of the emerging seedlings survived throughout the 3-month growth period in this treatment. All surviving seedlings under all treatments had the characteristic dark-green colour found to be associated, in this study, with litter plantings.

Field Observations

Data recorded as a result of dissecting six square-foot sods are shown in Table 6. The sods were obtained from range in excellent condition that was dominated by *F. scabrella*. During dissection, 58 identifiable seeds of *F. scabrella* were collected and 124 seedlings located. Germination under field conditions, therefore, was in the order of 68 per cent and 10.5 per cent of the resulting seedlings survived to mid-June. Comparable figures (Table 3) obtained in the greenhouse experiment were 70.2 per cent germination and 48.0 per cent survival. The latter would represent survival over a longer period of time since weather conditions would not permit germination on rangeland until late April or early May. Seed collected was bulked and two 25-seed lots were used in a germination test. Average germination of these seeds was only 6.5 per cent, suggesting that the carry-over of viable *F. scabrella* seed from year to year is negligible. Gross numbers given in Table 6 should be viewed in light of the fact that the seeding density used in the greenhouse studies was approximately 11 times that found on the 1958 sods, 1957 having been a poor seed year for *F. scabrella* in the collection area.

DISCUSSION

It is recognized that conditions for plant growth in the greenhouse are presumably optimum, particularly since moisture stress and the effects of widely fluctuating temperatures can be minimized. The results of this study, therefore, are not directly applicable to rangeland. They do provide a relative comparison among several of the variety of conditions

under which seedlings start growth on the range. Thus, although conducted under optimum growing conditions, the cumulative results of this study showed mortality in range grasses to be of a high order. In considering *F. scabrella*, the species most thoroughly studied, the percentage germination was significantly reduced as a result of soaking in water followed by exposure to a low temperature. This was comparable to the conditions that would be encountered on a field scale during the early spring months. A reduced percentage germination was noted with increasing depths of litter. Even with normal range carry-over, considerable quantities of this material are deposited on the surface after seed shattering each year and would be expected to further inhibit germination and prevent emergence. To this may be added the fact that viability of seed of the species did not exceed 86 per cent and that there are a myriad ways in which seeds may be destroyed between dissemination and opportunity for germination. The data showed that, even under greenhouse conditions, appreciable seedling mortality resulted from many of the growth conditions studied. As field observations indicated that mortality would be much greater under the more rigorous conditions on the range, it would be unrealistic to expect many plants to be produced as a result of natural seed dissemination. This lends support to the "closed community" concept and re-emphasizes the statement by Blake (1) that "on the prairie, seedlings find establishment difficult".

On the other hand, the results also show that, if conditions are favourable, seeds have a remarkable faculty of being able to germinate and the resulting seedlings to grow and persist. It can be seen readily that the production of an occasional large, viable seed crop is probably necessary in order to maintain a native grass stand in a strong, vigorous condition. As the production of such a seed crop would be dependent upon light or no grazing, the opportunity afforded existing plants to grow relatively unmolested during the season of food storage would be a factor in the maintenance of a vigorous stand.

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