Use of Asphalt-Emulsion Mulches to Hasten Grass-Seedling Establishment[1]

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Many attempts to establish plantings of blue grama grass *(Bouteloua gracilis)* in the Central Great Plains have failed. Repeated failures on experimental plots at Central Plains Experiment Range indicated a need for improved techniques in seeding this species. Soil-moisture measurements suggested that the rapid drying of the soil in the seed zone was probably a major cause of these grass-planting failures. Other workers have reported that synthetic mulching materials temporarily improve moisture condition in the top 1 inch of soil. Smith (1931) found that mulching with black asphalt paper increased soil temperature and was effective in conserving moisture in the surface 4 inches of soil. Rowe-Dutton (1957) reviewed 40 published reports showing response of certain vegetables to various mulching materials including aluminum foil, bituminous emulsion, paper, polyethylene plastic, and vermiculite. Carolus and Downes (1958), Army and Hudspeth (1959), and Honma et al. (1959) reported the changes in soil temperature and soil moisture resulting from the use of polyethylene-film mulches. Unpublished data from field trials conducted by Esso Research and Engineering Company in New Jersey indicated that a rapid-setting-emulsion asphalt mulch greatly reduced moisture loss from the seed zone. In 1959 exploratory tests of asphalt emulsified in unheated water were conducted at the Central Plains Experimental Range, 38 miles northeast of Fort Collins, Colorado, to determine the effect of asphalt mulches on the emergence and seedling establishment of sideoats grama *(Bouteloua curtipendula)* and blue grama grass.[4]

The experiments were conducted on land that had been plowed and abandoned and was in the *Aristida*-stage of secondary succession (Costello, 1944). The sandy-loam soil was described by Klipple and Retzer (1959) as belonging to the Ascalon series. The 21-year (1939-1959) average annual precipitation at the experimental site was 12.01 inches, with an average of 8.49 inches during the growing season May 1 to September 30. Growing-season precipitation for 1959 was 7.2 inches. Average wind velocity for the period June-October 1959 was 5.8 miles per hour. Average maximum and minimum air temperatures during June, July, and August 1959 were 85 and 53 degrees F., respectively. Average maximum air temperatures for September and October 1959 were 79 and 57, respectively, and average minimum temperatures were 46 for September and 28 for October.

Procedure

Replicated 25 by 5-foot plots were located on strips of ground that had been fallowed the previous summer. Grass was planted with a double-disk depth-band drill that placed seed in rows spaced 12 inches apart. Single-species plots were established with blue grama, sideoats grama, and Sudangrass *(Sorghum sudanense)*. Fiberglas soil-units, to indicate moisture and temperature, were placed in the blue grama and Sudangrass plots at 1-, 3-, 6-, and 12-inch depths.

On June 24 blue grama, sideoats grama, and Sudangrass were planted at the rates of 6, 3, and 12 pounds per acre respectively. The grama grasses were planted using ⅝-inch depth bands on the drill. The depth bands were removed when the Sudengrass was planted.

Two asphalt emulsions, a rapid-setting emulsion developed by Esso for mulching, and the standard, slow-setting, road-mixing emulsion available commercially, were used in each of 3 treatments. One treatment was 100-percent coverage with the asphalt film sprayed over the entire plot. The second treatment was 50-percent coverage with a

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[1] *Colorado Agricultural Experiment Station Scientific Journal Article No. 664.*

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[4] *Research reported in this article was made possible by a grant from Esso Research and Engineering Company.*

coating of asphalt 6 inches wide centered over the seeded row. The third treatment was 25-percent coverage with a coating 3 inches wide centered over the seeded row. Asphalt was not applied to the check plots.

On June 25 rapid-setting emulsion was sprayed on the plots. An amount of water equivalent to .07 of an inch of precipitation was applied with the asphalt. This amount of water was also applied to the check plots. For 50- and 25-percent coverages, boards were used to mask the areas between the asphalt strips. The spraying was done with a compressed-air pump operated from a tractor compressor. On June 26 the slow-setting emulsion was applied to plots designated for its use. Soil-moisture content was determined gravimetrically at weekly intervals. An electrical soil-moisture instrument was used to take soil-moisture and soil-temperature readings twice daily. For soils at the 1-inch and 3-inch depths the relation between soil-moisture content and soil-unit resistance readings was determined in the laboratory. The method used was similar to that described by Kelley (1944). Air-temperature and wind-velocity measurements were made with standard Weather Bureau equipment. Each week the plants per foot of seeded row were counted and leaf lengths measured. A leaf-surface index for use in graphs was obtained by multiplying the average number of plants per foot of row by the average leaf length in centimeters.

Results

By June 30, six days after seeding, plants of all 3 species had penetrated the asphalt mulch. Blue grama and sideoats grama plants did not emerge in check plots until mid-July. The Sudangrass emerged and developed in all treated plots and the check plots simultaneously. The rapidity with which the blue grama seedlings emerged and developed in the asphalt-treated plots was the outstanding feature of the study. By early August, less than 60 days after the seeds had been planted, many of the blue grama plants in the mulched area were producing seed heads. The few plants that remained in the check plots were small and spindly. During the winter of 1959-1960 nearly all of these blue grama plants in the check plots died. The blue grama plants in the mulched plots survived the winter and again produced seed heads during the summer of 1960.

Seedling Emergence and Survival

Blue grama

Uniformly-abundant emergence of blue grama seedlings was observed in the asphalt-treated plots 5 days after planting. A mass emergence was not observed in the check plots until 28 days after planting. Seed-zone moisture under the rapid-setting emulsion remained relatively high through July 10 (Figure 1). The seed zone under the slow-setting emulsion dried a few days earlier and the seed zone in the check remained relatively dry until July 14 (Figure 2). Mass emergence in the check was observed July 22, after the seed zone had been relatively moist for 6 days. The 6-day period of higher moisture required to start emergence in the check corresponds closely to the 5-day period required to start emergence under the asphalt mulch. The approximate wilting point of these soils corresponds to the logarithm of resistance of 6 (Figures 1 and 2). Field capacity is near the logarithm of resistance of 3. Soil moisture at the 1-inch depth remained above the wilting point for approximately 16 days for the 25-percent and 17 days after application for the 50- and 100-percent coverages of rapid-setting emulsion. Similarly, soil moisture at the 1-inch depth under the slow-setting emulsion remained above wilt-

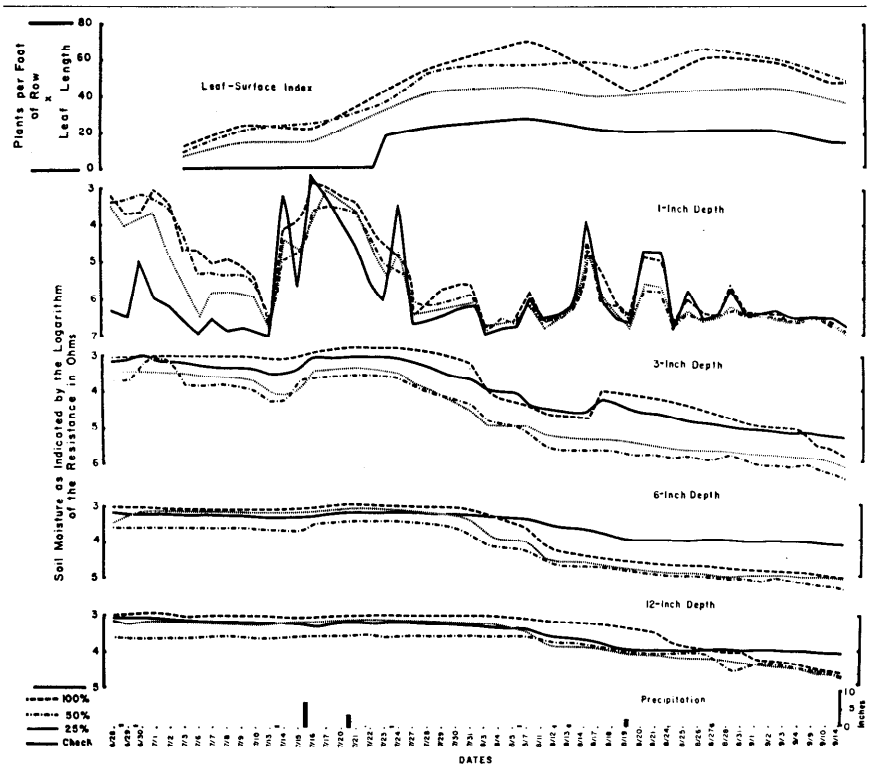

FIGURE 1. Relation between precipitation, soil moisture, and blue grama leaf-surface index in the check plots and plots with 100-, 50-, and 25-percent coverage of rapid-setting-emulsion asphalt mulch.

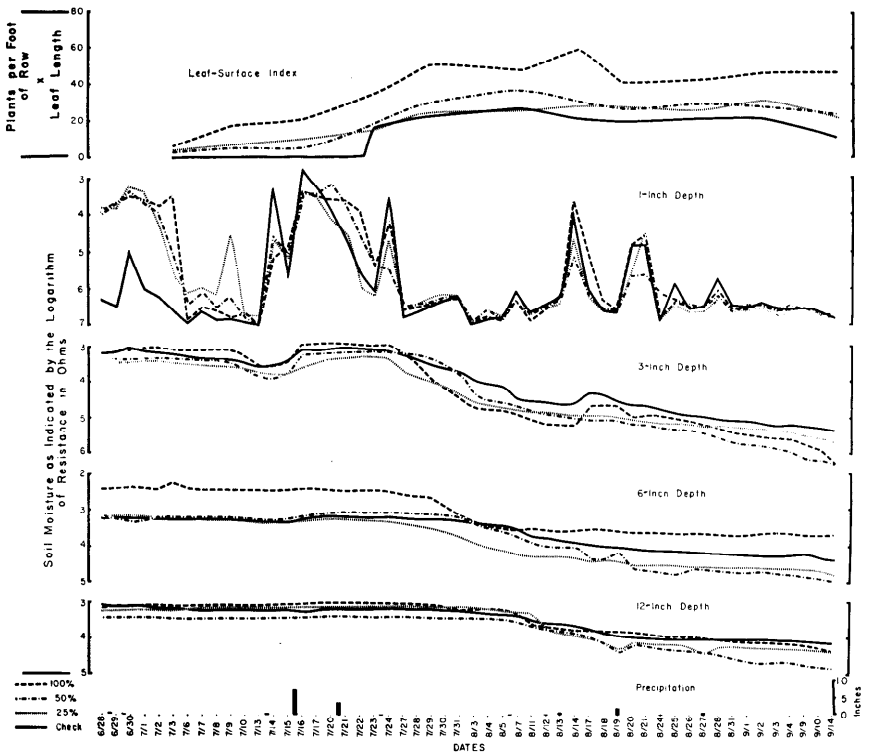

FIGURE 2. Relation between precipitation, soil moisture, and blue grama leaf-surface index in the check plots and plots with 100-, 50-, and 25-percent coverage of slow-setting-emulsion asphalt mulch.

point for 9 days after application for all coverages. In contrast, the seed zone of the untreated plots remained below wilting point from the day of grass sowing until July 14, a period of 20 days. These differences in soil moisture in the seed zone apparently account for the difference in rate of seed germination and subsequent seedling growth. In general, seed-zone temperatures under the asphalt mulch were higher than those in the check plots and temperatures under the rapid-setting asphalt film were slightly higher than those under the slow-setting emulsion (Table 1). The asphalt films provided an effective barrier for reduction of soil-moisture losses by evaporation for approximately 3 weeks after application. On the evening of July 15 a high-intensity storm deposited 0.71 inch of precipitation including hail. This storm caused some damage to the asphalt film and reduced its moisture-preserving ability. The wide spread in moisture content that existed between the asphalt and check plots prior to this storm did not occur again (Figures 1 and 2).

Nearly as many or more plants emerged in the rapid-setting emulsion plots as in the check (Table 2). By fall the 100- and 50-percent coverages of rapid-setting emulsion had nearly twice as many surviving plants as the check. On the slow-setting emulsion plots, the number of plants emerging through the 25- and 50-percent coverages was never as high as the number of plants emerging in either the 100-percent coverage or the check. With slow-setting emulsion, plant survival was highest in the 100-percent coverage plots and uniformly lower in the 50- and 25-percent coverage plots and the check (Table 2).

Blue grama plant counts in October showed that all coverages of the rapid-setting emulsion were effective in increasing seedling establishment. Plant numbers in the 50- and 100-percent coverages were significantly different from those in the check at the 1-percent level, and plant numbers in the 25-percent coverage were different from the check at the 10-percent level of probability. Pictures in Figure 3 show the blue grama in the plots treated with the rapid-setting emulsion.

Only the 100-percent coverage of slow-setting emulsion was highly effective. Plant numbers in this coverage were significantly different from the check at the 1-percent level. The other treatments with the slow-setting emulsion were not significantly different from the check. Pictures in Figure 4 show the blue grama in plots treated with the slow-setting emulsion. The 100- and 50-percent coverages of the rapid-setting emulsion and the 100-percent coverage of slow-setting emulsion were not signifi-

Table 1. Average morning and afternoon soil temperatures in degrees Fahrenheit at four soil depths in the blue grama check plots and plots with 100-, 50-, and 25-percent coverage of two asphalt mulches for the period June 28 to July 30, 1959.

Depth	Check		Rapid-setting emulsion						Slow-setting emulsion					
			25		50		100		25		50		100	
Inches	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
1	86.4	92.3	89.1	94.7	90.0	95.1	94.6	99.1	90.1	96.7	89.0	93.6	88.1	94.6
3	76.3	87.4	76.5	90.0	80.0	93.6	75.9	90.8	77.3	91.8	79.9	93.1	81.0	96.2
6	73.9	82.7	74.9	85.1	76.0	87.4	76.8	89.8	73.3	85.6	75.5	88.6	76.0	89.0
12	73.9	76.0	74.9	78.6	75.9	78.8	78.9	82.1	73.3	75.8	75.1	79.3	78.6	81.6

Table 2. Average numbers of live blue grama, sideoats grama, and Sudangrass plants per foot of seeded row on check plots and plots with 100-, 50-, and 25-percent coverage of two asphalt mulches.

Kind of mulch and counting dates for blue grama and Sudangrass	Blue grama				Sudangrass				Sideoats grama				Sideoats grama counting dates
	Asphalt coverage				Asphalt coverage				Asphalt coverage				
	100	50	25	Check	100	50	25	Check	100	50	25	Check	
Rapid-setting emulsion:													
July 3, 1959	16.8	13.2	8.3	0.0	4.2	10.0	8.4	16.2	5.3	8.5	2.1	0.0	July 3, 1959
July 9, 1959	13.9	11.9	7.0	0.0	5.2	6.2	7.4	14.0	3.6	3.4	0.9	0.0	July 9, 1959
July 16, 1959	11.5	11.6	7.2	0.0	4.5	5.0	7.9	12.0	1.9	1.8	0.7	0.0	July 16, 1959
July 23, 1959	15.0	14.6	11.7	14.0	5.0	4.9	7.4	12.1	4.0	5.8	5.7	6.9	July 23, 1959
July 28, 1959	12.4	13.2	9.9	11.8	4.6	4.7	7.0	13.4	2.7	3.4	4.6	6.5	July 31, 1959
Aug. 7, 1959	10.2	10.0	7.3	8.0	4.3	5.1	6.8	11.5	3.4	3.6	4.7	6.4	Aug. 8, 1959
Aug. 14, 1959	7.9	8.0	6.1	5.6	3.5	4.1	6.0	10.6	2.0	2.4	2.6	3.6	Aug. 14, 1959
Aug. 19, 1959	5.8	6.9	5.5	4.8	3.4	3.9	6.9	9.9	1.8	1.9	2.9	3.4	Aug. 19, 1959
Aug. 26, 1959	7.2	7.2	5.4	4.3	3.0	5.0	6.7	9.9	1.6	2.0	2.2	2.8	Aug. 27, 1959
Sept. 2, 1959	6.2	6.0	4.8	3.9					1.4	1.5	2.0	1.7	Sept. 1, 1959
Sept. 14, 1959	4.7	5.0	3.4	2.7					0.0	0.0	0.0	0.0	June 27, 1960
Sept. 26, 1959	4.9	5.0	3.2	2.7									
Oct. 3, 1959	4.8	5.1	3.7	3.1									
Oct. 24, 1959	4.5	4.7	3.4	2.5									
June 27, 1960	3.6	3.2	2.6	0.2									
Slow-setting emulsion:													
July 3, 1959	10.4	4.0	5.2	0.0	8.2	5.8	9.5	16.2	1.4	0.5	0.5	0.0	July 3, 1959
July 9, 1959	11.0	3.5	4.1	0.0	8.3	5.7	7.8	14.0	1.5	0.5	0.6	0.0	July 9, 1959
July 16, 1959	10.1	2.7	5.2	0.0	6.8	3.9	7.2	12.0	1.0	0.4	0.6	0.0	July 16, 1959
July 23, 1959	14.5	9.6	6.9	14.0	7.6	4.0	7.5	12.1	3.4	1.4	3.3	6.9	July 23, 1959
July 28, 1959	11.5	9.6	8.2	11.8	7.0	4.3	7.1	13.4	2.8	1.7	3.1	6.5	July 31, 1959
Aug. 7, 1959	9.4	7.8	5.5	8.0	6.2	4.2	6.8	11.5	3.3	1.9	3.6	6.4	Aug. 8, 1959
Aug. 14, 1959	9.0	5.8	4.8	5.6	7.1	3.6	3.6	10.6	2.8	1.3	1.5	3.6	Aug. 14, 1959
Aug. 19, 1959	6.7	4.5	4.4	4.8	6.1	3.8	9.0	9.9	2.4	1.1	1.5	3.4	Aug. 19, 1959
Aug. 26, 1959	5.9	4.6	3.8	4.3	7.7	3.8	6.3	9.9	2.2	1.0	1.2	2.3	Aug. 27, 1959
Sept. 2, 1959	6.8	4.0	4.0	3.9					1.7	0.8	0.8	1.7	Sept. 1, 1959
Sept. 14, 1959	5.0	3.6	2.8	2.7					0.0	0.0	0.0	0.0	June 27, 1960
Sept. 26, 1959	5.3	3.3	2.8	2.7									
Oct. 3, 1959	5.1	3.5	2.6	3.1									
Oct. 24, 1959	4.8	2.8	2.8	2.5									
June 27, 1960	2.3	1.8	0.4	0.2									

cantly different from one another. Figure 5 shows one of the check plots.

Sideoats grama

Sideoats grama emergence occurred more quickly under the asphalt mulch than in the check. A larger number of plants emerged in the rapid-setting-emulsion, asphalt-mulched plots than in the slow-setting-emulsion plots (Table 2). The dry period prior to July 13 resulted in nearly 50-percent seedling die-out of sideoats grama in the rapid-setting-emulsion plots. The total number of surviving plants on September 1 was quite similar for the check, all rapid-setting-emulsion plots, and the 100-percent coverage slow-setting-emulsion plots. Survival was lower in the other slow-setting-emulsion plots. Sideoats grama plant counts in September indicate that the asphalt mulch had little beneficial effect on establishment. None of the sideoats grama plants survived the winter of 1959-60. The species is not as drought-resistant and apparently not as well adapted for this area as blue grama.

Sudangrass

The ability of the various species to penetrate the asphalt film was not known. Although Sudangrass is easily established in this area without mulching, it was used because it has greater seedling vigor than the gramas. A direct relationship was assumed to exist between seedling vigor and a plant's ability to penetrate the asphalt film.

Sudangrass emergence was just as rapid in the check as in the asphalt plots, and the number of plants per foot of row was higher in the check at all times (Table 2). Generally in the rapid-setting-emulsion plots the number of plants decreased as the asphalt coverage increased. This relation does not exist in the slow-setting-emulsion plots. Plant numbers are similar in the 25- and 100-percent asphalt-coverage plots and higher than those in the 50-percent coverage plots. Sudangrass plant counts

FIGURE 3. Blue grama plots with the rapid-setting-emulsion asphalt mulch in January 1959. Percent asphalt coverage from left to right was 100, 50, and 25.

Table 3. Average leaf length (centimeters) of blue grama, sideoats grama, and Sudangrass plants on check plots and plots with 100-, 50-, and 25-percent coverage of two asphalt mulches.

Kind of mulch and measuring dates for blue grama and Sudangrass	Blue grama				Sudangrass				Sideoats grama				Sideoats grama measuring dates
	Asphalt coverage				Asphalt coverage				Asphalt coverage				
	100	50	25	Check	100	50	25	Check	100	50	25	Check	
Rapid-setting emulsion:													
July 3, 1959	0.7	0.6	0.8	0.0	2.7	2.8	2.9	3.1	0.6	0.6	0.6	0.0	July 3, 1959
July 9, 1959	1.6	1.8	2.0	0.0	5.6	5.7	5.7	5.8	0.9	2.2	1.6	0.0	July 9, 1959
July 16, 1959	1.8	2.0	1.9	0.0	9.7	9.0	9.7	9.4	1.4	2.8	2.8	0.0	July 16, 1959
July 23, 1959	2.8	2.4	3.0	1.2	17.0	17.4	15.1	16.5	2.1	2.8	2.2	1.4	July 23, 1959
July 28, 1959	4.3	3.9	4.2	1.8	25.0	26.4	26.8	24.5	3.6	4.4	2.3	2.2	July 31, 1959
Aug. 7, 1959	6.8	5.8	6.0	3.4	36.4	40.5	35.8	37.8	4.4	6.2	4.1	3.6	Aug. 8, 1959
Aug. 14, 1959	6.8	7.1	6.2	3.6	44.6	47.0	43.0	45.1	6.1	6.1	5.0	3.9	Aug. 14, 1959
Aug. 19, 1959	6.8	7.8	7.2	4.0	54.9	51.6	47.6	53.1	6.0	5.2	5.2	4.2	Aug. 19, 1959
Aug. 26, 1959	7.8	9.1	7.5	4.8	54.0	56.6	55.4	51.6	6.4	6.5	6.5	5.0	Aug. 27, 1959
Sept. 2, 1959	9.0	9.8	9.0	5.1					5.7	6.9	6.3	5.2	Sept. 1, 1959
Sept. 14, 1959	9.6	9.2	9.8	5.2					0.0	0.0	0.0	0.0	June 27. 1960
Sept. 26, 1959	9.4	9.0	10.4	5.0									
Oct. 3, 1959	8.8	9.0	9.7	4.8									
Oct. 24, 1959	8.4	8.4	9.4	5.0									
June 27, 1960	11.6	10.3	10.0	10.8									
Slow-setting emulsion:													
July 3, 1959	0.7	0.6	0.8	0.0	2.4	2.6	3.0	3.1	0.6	0.6	0.6	0.0	July 3, 1959
July 9, 1959	1.8	1.5	1.6	0.0	5.6	5.8	6.2	5.8	1.4	1.2	1.5	0.0	July 9, 1959
July 16, 1959	1.8	1.6	1.8	0.0	8.8	11.2	9.7	9.4	2.2	1.5	1.6	0.0	July 16, 1959
July 23, 1959	2.4	1.9	2.2	1.2	17.8	17.2	15.8	16.5	2.0	1.6	1.4	1.4	July 23, 1959
July 28, 1959	4.0	3.0	3.0	1.8	22.4	25.3	22.5	24.5	3.1	2.9	2.6	2.2	July 31, 1959
Aug. 7, 1959	4.8	4.8	4.4	3.4	33.0	41.4	27.2	37.8	4.8	5.0	3.2	3.6	Aug. 8, 1959
Aug. 14, 1959	6.4	5.2	5.8	3.6	40.8	41.2	34.7	45.1	5.6	4.6	4.3	3.9	Aug. 14, 1959
Aug. 19, 1959	6.0	5.8	6.0	4.0	45.1	45.5	34.2	53.1	6.0	5.0	4.2	4.2	Aug. 19,..1959
Aug. 26, 1959	7.0	6.2	6.5	4.8	55.7	58.6	46.8	51.6	6.7	5.4	4.8	5.0	Aug. 27, 1959
Sept. 2, 1959	6.8	6.8	7.1	5.1					6.4	6.6	5.8	5.2	Sept. 1, 1959
Sept. 14, 1959	9.2	6.5	7.6	5.2					0.0	0.0	0.0	0.0	June 27, 1960
Sept. 26, 1959	7.9	6.4	8.2	5.0									
Oct. 3, 1959	8.4	6.6	7.7	4.8									
Oct. 24, 1959	7.9	6.5	7.0	5.0									
June 27, 1960	9.0	8.3	7.6	10.8									

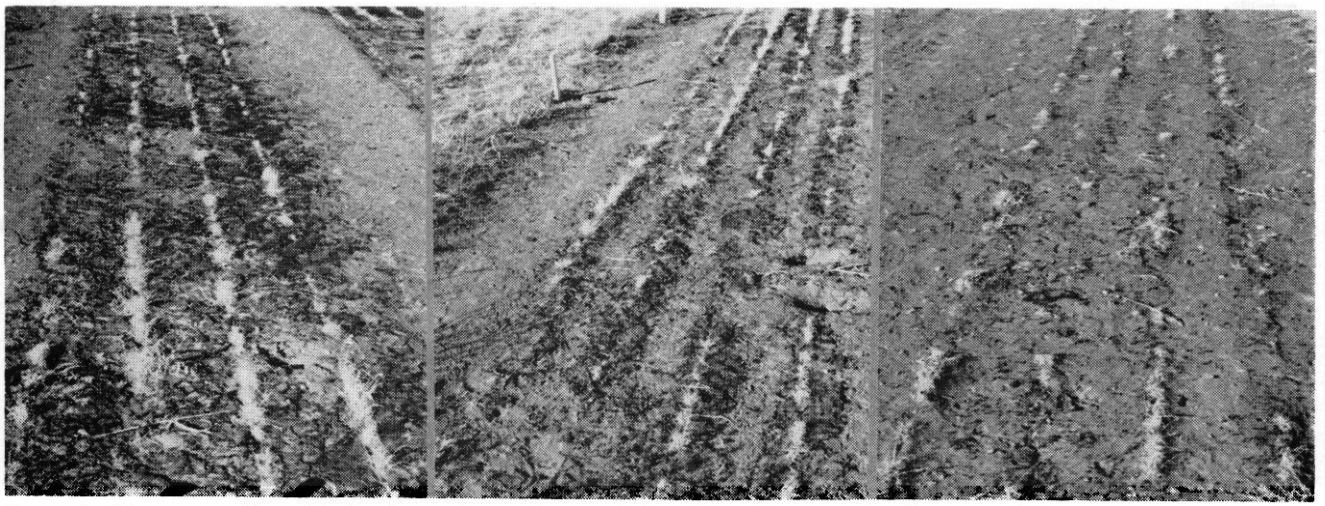

FIGURE 4. Blue grama plots with the slow-setting-emulsion asphalt mulch in January 1959. Percent asphalt coverage from left to right was 100, 50, and 25.

indicate that the asphalt mulch had a detrimental effect on its establishment.

Leaf Growth
Blue grama

Blue grama plants in the asphalt plots emerged 3 weeks before those in the check. The rate of leaf growth during the first month after emergence was about the same in all treated plots and the check (Table 3). Average leaf length 1 month after emergence was approximately 1.8 centimeters on all plots. After plants were 1 month old the rate of growth was much more rapid in the rapid-setting-emulsion plots and the 100-percent coverage slow-setting emulsion plots than it was in the plots with the other treatments. On October 24 the leaf length of the surviving blue grama plants was greater in the rapid-setting-emulsion plots than in the check. Although blue grama growth in the slow-setting-emulsion plots was more than in the check, it was less than in any of the rapid-setting-emulsion plots. Blue grama leaf lengths in all asphalt-treated plots were significantly different from the check at the 1-percent level.

During the very dry first half of August when many of the seedlings died, those that survived continued to grow. Much of this growth was apparently made on moisture from the 3-inch depth. This is particularly noticeable in the 100-percent coverage plots of the rapid-setting emulsion (Figure 1). During this dry period, July 29 through August 14, blue grama in these plots had the highest index of leaf surface of any of the treated plots. Soil moisture at the 3-inch depth decreased markedly during this same period. On August 14 seed heads had started to form on some of the more mature plants.

Soil moisture at the 6-inch depth remained relatively con-

FIGURE 5. Blue grama check plot in the immediate foreground in January 1959.

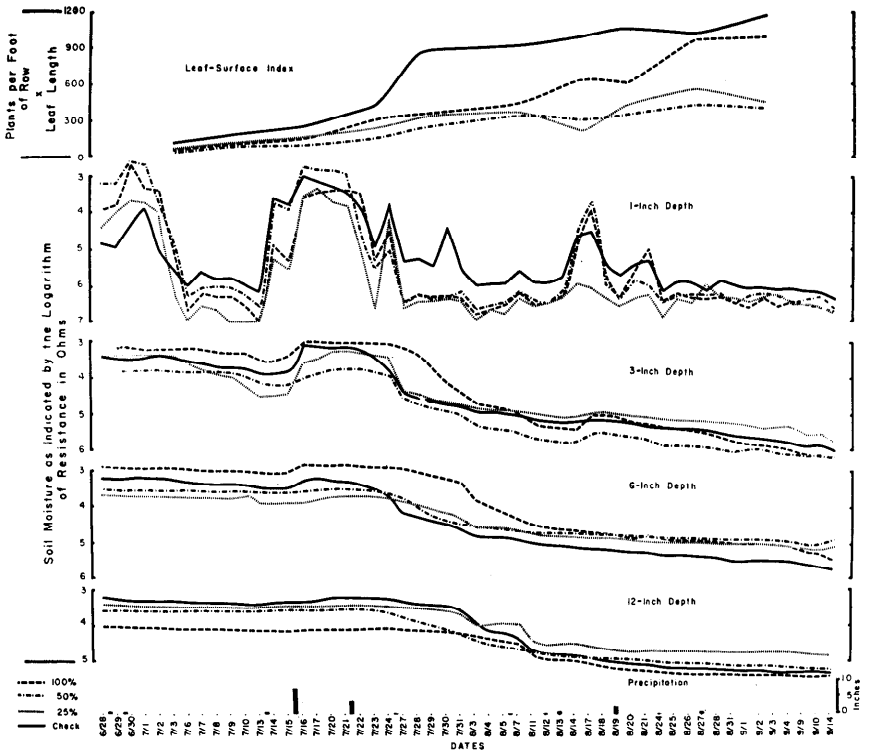

FIGURE 6. Relation between precipitation, soil moisture, and Sudangrass leaf-surface index in the check plot and plots with 100-, 50-, and 25-percent coverage of slow-setting-emulsion asphalt mulch.

stant until July 30 in all plots (Figure 1). From this date on, blue grama plants in the asphalt plots used moisture from this depth. Soil moisture at the 12-inch depth remained relatively constant until August 4 (Figure 1). Moisture depletion was relatively similar between plots from August 4 until August 21. After August 21 the plants on the 100-percent asphalt-covered plots appeared to draw more heavily on the soil moisture from this zone than did plants given the other treatments.

Sideoats grama

Leaf lengths of sideoats grama on September 1 were somewhat greater in all the asphalt-treated plots than in the check (Table 3). The rate of growth during the first month after emergence was about the same for all treated plots and the check.

Sudangrass

Leaf lengths for Sudangrass on all rapid-setting asphalt-treated plots are comparable to the check on each plant-count date (Table 3). This was also true in the slow-setting asphalt-treated plots until August 7. After that date the leaf length on the slow-setting-emulsion 25-percent-coverage plots was shorter than that on the other plots. Most of the moisture at the 1-inch depth in the 25-percent-coverage plots was lower than that in the other plots (Figure 6). This was particularly noticeable from August 13 to August 19, when plants in the other plots made more rapid growth.

Discussion

The favorable results obtained with the rapid-setting-emulsion asphalt mulch on blue grama are encouraging. Results obtained with asphalt mulches on sideoats grama and Sudangrass dictate a word of caution. The reaction of a given species to an asphalt mulch should be carefully checked before any large scale use of a mulch on the species concerned is recommended. Many factors that affect germination are altered by the asphalt mulch. This study gives some indication of the changes brought about in soil moisture and temperature. Other factors influencing germination which might be altered by an asphalt mulch are light, aeration, pH value, and chemical composition of the soil. The one season's results are not considered sufficient for recommendations for the species tested.

Summary and Conclusions

The effect of two asphalt-emulsion mulches on the establishment of blue grama, sideoats grama, and Sudangrass was studied at Central Plains Experimental Range. Results were interpreted in terms of soil moisture, soil temperature, plant emergence, plant growth and plant survival. This study makes the following conclusions possible:

1. In one-season exploratory tests, emergence and development of blue grama plants were hastened by the use of an asphalt mulch.
2. The net effect of an asphalt mulch on seedling establishment varied considerably with the kind of asphalt used and the species planted.
3. Seed and plant reactions to asphalt mulching should be carefully checked before an asphalt mulch is recommended for establishment of any species.
4. Soil moisture at the 1-inch depth was maintained for a longer period under an asphalt mulch than in the check.
5. Soil temperatures from the 1-inch depth through the 12-inch depth were higher under an asphalt mulch than in the check.
6. The rapid-setting-emulsion asphalt mulch held moisture and increased temper-

ature for a longer period than did the slow-setting-emulsion asphalt mulch.

7. The moisture-holding ability of the asphalt mulch was reduced by high-intensity rainstorms or hailstorms which tended to break up the film.

LITERATURE CITED

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