Effects of Oat Straw and Native Hay Mulches on Plant Composition and Edaphic Factors of a Revegetating, Abandoned Field[1]

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In the winter of 1949-1950 a five-year program on the effects of mulching was inaugurated at the Grassland Investigations Project, eight miles southwest of Norman, Oklahoma. The purposes of the program were to ascertain the rate of decomposition of mulch and to determine the effects of mulching on plant production and plant succession, and on hydrogen-ion concentration, organic carbon, volume weight, and water content of the underlying soil. Unfortunately, in January, 1952, a devastating fire jumped the protecting firebreak and terminated the mulch investigations. This paper presents those results of the first two years (1950, 1951) of the program which may be of interest to grassland students in the area.

Methods

The mulch plots were located in a revegetating field, abandoned in 1941. At the time the mulch was applied (February, 1950) the field was dominated by *Aristida oligantha* and had a natural mulch averaging 4416 pounds per acre. Four square mulch plots of one-sixteenth acre each (in a block) were prepared by adding either oat straw or native hay. The designation of the plots and the total amounts of mulch (including the natural mulch) in pounds per acre, were as follows: medium straw, 7672; heavy straw, 15585; medium hay, 7270; and heavy hay, 11820 (Table I).

TABLE I

Number of Species in Quadrats, Total Areal Cover, and Oven-dry Weight of Green Herbage and Total Mulch on Mulch Plots. Standard errors in parenthesis.

Item	Year	Control	Oat straw		Native hay	
			Medium	Heavy	Medium	Heavy
No. species	1950	28	19	14	21	15
	1951	34	21	13	20	14
Total cover	1950	74	73	41	42	32
(per cent)	1951	83	84	63	44	34
Green herbage	1950	2780	3300	2370	2164	1720
(lbs./acre)		(205)	(240)	(285)	(240)	(232)
	1951	2694	2855	2346	1918	1570
		(303)	(259)	(250)	(152)	(268)
	1950	4416*	7672*	15585*	7270*	11820*
Total mulch	Feb.	(1180)	(1000)	(2230)	(562)	(1200)
(lbs./acre)	1950	2895	7580	9990	7950	14000
	Fall	(250)	(348)	(276)	(312)	(104)
	1951	3497	8764	10500	8439	12944
	Fall	(276)	(491)	(428)	(410)	(607)

* Based on 10 subsamples; all others on 25 subsamples.

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The vegetation was sampled in the control and in each of the four mulch plots in May, 1950, October, 1950, and late August, 1951. Twenty-five 0.1 sq. m. quadrats were utilized in each plot for determining percentage frequency and percentage areal cover for each species present. After each quadrat analysis, the plant material was clipped for subsequent determination of the oven-dry weight of living material (green herbage) and dead material (mulch).

Soil samples for the determination of organic carbon, *p*H, and soil moisture were taken from the 0-6 inch and 12-18 inch levels. Organic carbon (Walkley and Black Method) and *p*H were determined by the methods outlined by Piper (5). In the preparation of the soil samples for the above determinations, all organic matter was thoroughly ground and mixed with the sample. Volume-weight determinations of the soil were made at a depth of 0-3 inches.

Results

The main effect of the mulch during the first two growing seasons (1950, 1951) was to prevent the ecesis of many plants and presumably to retard succession except possibly in the medium straw mulch plot. By the end of the first growing season, at least one-half of the species in the control had become established in each of the mulch plots (Table I). More species were found in the medium mulch plots than in the heavy mulch units. The number of species had not changed appreciably by the end of the next growing season (Table I). Excepting cultivated oats, no species was encountered in the mulch plots that was not present in the control area.

The total areal foliage cover in the autumn of 1950 was similar in the control and medium straw mulch units, similar but much lower in the heavy straw and medium hay plots, and lowest in the heavy hay mulch plot (Table I). Apparently the higher cover in the straw unit, as compared with the hay plot, was due to the more rapid deterioration of the oat straw mulch. An increase in cover for all units had taken place by the end of the 1951 growing season, especially in the oat straw plots (Table I). It will be observed that no appreciable increase occurred in the native hay plots, due to the low rate of decay of the native hay mulch.

The oven-dry weight of green herbage for both years was lower in the control than it was in the medium oat straw mulch, but greater than that of any of the other plots (Table I). The lowest amount of herbage, as in the case of total areal cover, was encountered in the native hay mulch plots. Unlike areal cover, the amount of herbage was greater in 1950 than in 1951 (Table I).

It was expected that a considerable decrease in the amount of mulch would occur from season to season but no such trend was noted. Although the data extend only over two growing seasons and are not particularly reliable, they do suggest that the rates of accretion of natural mulch, via green herbage, and of decay of total mulch were similar (Table I).

At the time the mulch program was being formulated (Autumn, 1949), *Aristida oligantha* was the only dominant in the control plot. By the autumn of 1950, however, *Lespedeza stipulacea* and *Panicum scribnerianum* had also attained the status of dominants, due possibly to the protection of the area from grazing animals. In the autumn of 1950, the average cover percentages of the three dominants in the control plot were as follows: *Aristida oligantha*, 37.3; *Lespedeza stipulacea*, 12.2, and *Panicum scribneridnum*, 10.0. By the Autumn of 1951, the areal cover of *Aristida oligantha* had decreased considerably, and that of *Leptoloma cognatum* had increased almost as much (Table II.)

TABLE II

Effect of Two Years of Mulch on the Plant Cover of a Revegetating Abandoned Field. Each entry is an average of twenty-five quadrats with standard error.

Species	Control	Oat straw		Native hay	
		Medium	Heavy	Medium	Heavy
Leptoloma cognatum	17.9±4.7	5.4±2.1*	1.4±0.6#	13.6±3.7	5.2±2.2*
Aristida oligantha	15.4±2.8	1.6±0.6#	tr.	2.5±0.8#	0.5±0.4#
Lespedeza stipulacea	14.0±2.4	31.8±4.1#	20.0±5.5	8.6±1.6	0.8±0.4#
Panicum scribnerianum	13.9±3.0	10.0±2.5	13.6±2.4	12.0±3.2	14.3±3.6
Aster ericoides	0.9±0.4	14.9±4.5#	11.5±3.5#	2.1±0.8	3.3±1.7
Ambrosia psilostachya	0.7±0.3	7.2±3.1*	10.2±2.5#	0.8±0.3	4.8±1.6*

* Difference from control significant at .05 level
\# Difference from control significant at .01 level.

The differences in plant composition in the mulch plots from the control were similar in 1950 and 1951. For this reason, and in the interest of economy, the results for 1951 only are presented (Table II). Plants became established more readily in medium mulch than in heavy applications of the same material. With few exceptions, species exhibited greater percentage cover in the oat straw than in the native hay plots (Table II). *Panicum scribnerianum* was unique in being able to effect ecesis about equally well in all plots (Table II). The most striking vegetational change was the great decrease in cover of *Aristida oligantha* with an attendant increase in *Lespedeza stipulacea* in the medium straw plot as compared with the control. The weedy forbs exhibited greater coverage in the mulch plots than in the control.

Although 25 quadrats were utilized in the analysis of each plot, the standard errors were relatively large, suggesting considerable heterogeneity in the plant populations. Because of the fairly large standard errors, many apparently large differences between mean cover percentages were not statistically significant (Table II). The experiences of the authors in this study, and in other analyses of plant populations in grasslands, suggest a greater need for statistical studies on grassland vegetation.

Edaphic Factors

The hydrogen-ion concentration was lowest in the spring (5.6-6.3) and highest in late autumn (6.3-6.8). There was no appreciable difference between the *p*H values at 0-6 inches and 12-18 inches. No differences or trends could be correlated with the kind or amount of mulch.

The typical range in the per cent of organic carbon was 0.80 to 0.90 (Walkley and Black Values) for the 0-6 inch level and 0.30 to 0.50 at the 12-18 inch depth. No correlation could be made with the kinds or amounts of mulch except for the 1951 determination at 0-6 inches in the medium oat straw plot. Earthworms, insects, field mice, and pocket gophers apparently had mixed considerable organic matter with the upper soil, with the result that an average of 1.10 per cent of organic carbon was obtained as against previous readings of 0.84, 0.84, and 0.86. Indications are that the organic carbon in the upper soil would have increased in the other plots had the experiment not been discontinued because of fire.

In the spring of 1950, only two months after the mulches were applied, it was noted that the soil appeared firmer under the applied mulches than in the control. During the summer and autumn of 1950 it was more difficult to obtain soil samples in the harder soil under the mulches than in the control area, although the condition had disappeared by the spring of 1951. On October 29, 1950, volume weight determinations were 1.1 in the control

and 1.2 in all mulch plots except under the heavy straw where it was 1.3. The value under the heavy straw mulch was significantly higher (.01 level) than in the control. Increased volume weight in mulched plowed prairie over unmulched plowed prairie was reported by Rice and Penfound (6). This unexpected increase in volume weight may be related to the leachates from the surficial mulch or possibly to a modification of the usual freezing-thawing cycles.

Since the differences in soil moisture between the mulch plots and the control were similar in 1950 and 1951, only the record for 1950 is presented here (Table III). In general the soil moisture percentages were similar in the control and under the medium straw mulch, were similar but higher under the heavy oat straw and medium native hay, and highest under the heavy native hay mulch (Table III). Differences in moisture content between the control and the heavy hay plot were as much as 7.7 per cent at a depth of 0-6 inches and as much as 4.8 per cent at the 12-18 inch level. From the present data it appears that native hay is more effective than oat straw in preventing loss of soil moisture (Tables I and III). Whether this phenomenon is due to some inherent quality in native hay or whether it is due to the lower number of plants (and lower transpiration) in the hay mulch plots is not known.

TABLE III

Soil Moisture (per cent with standard error) in Mulch Plots on a Revegetating, Abandoned Field. Each figure for the mulch plots represents an average of 4 determinations except for 6 samples each on March 31, 1951. Each figure for the control is an average of 6 samples.

Sampling time	Control	Oat straw		Native hay	
		Medium	Heavy	Medium	Heavy
		0-6 inches			
Apr. 19, 1950	21.4± .2	20.6± .9	24.3± .5#	21.5± .9	22.6± .5
June 27, 1950	11.8± .8	12.0±1.8	16.7± .5#	15.0± .8*	19.5± .4#
Sept. 6, 1950	9.8± .2	7.6± .7*	12.3± .7#	11.0± .5	14.6±1.2#
Nov. 2, 1950	10.0± .5	9.0±1.4	9.4± .9	12.8±2.8	12.7± .7*
Mar. 31, 1951	20.7± .5	20.1± .7	22.1± .4	20.8± .4	21.5± .3
		12-18 inches			
Apr. 19, 1950	20.3± .1	18.4± .5#	19.2± .7	18.1±1.0	21.0±1.0
June 27, 1950	15.1± .8	14.4±1.2	17.2± .4	15.7±2.7	19.9±1.0#
Nov. 2, 1950	13.6±1.0	9.3±1.0*	12.7±1.5	16.2± .9	16.2±1.8
Mar. 31, 1951	19.9± .5	19.1± .4	19.8± .6	19.3± .5	20.4± .6

Difference from control significant at .01 level.
* Difference from control significant at .05 level.

Discussion

The question has been raised as to why such heavy applications of mulch were utilized in this investigation. The plan was to apply quantities of mulch typically found in grasslands of the region and of sufficient quantity so that some mulch would be present at the end of the five-year period. Dyksterhuis and Schmutz (3) listed air-dry weights of natural mulches (in pounds per acre) for the Fort Worth Prairie, Texas, as follows: range in fair condition, 1558; native hay meadow, 1938; range in excellent condition, 5321; relict of climax, 9037. Tomanek (8) reported litter (in pounds per acre) on Kansas native pastures as follows: moderately grazed, 930; undergrazed, 1989; and ungrazed, 2004. Kelting (4) found even

higher oven-dry weights of natural mulch in the immediate vicinity of the current investigation; lightly grazed native pasture, 8831; virgin prairie, 9544; protected native pasture (ungrazed for one year), 11221. In the current investigation, the following amounts of mulch (in pounds per acre) were applied to prepare the four mulch plots: 3256 and 11169 of oat straw, 2854 and 7404 of native prairie hay. These quantities are within the range of the amounts found in grasslands of the southwest. Data collected during the first two years indicate that some oat straw and considerable native hay mulch would have remained at the end of the program had a similar rate of decomposition continued throughout the five-year period.

One important problem in grasslands is to ascertain the relative rates of accumulation and decay of natural mulch during prairie succession. Sims (7) reported that the normal accumulation of litter in the pine-oak forest weighed two or three times as much as that deposited in one year. The data for Texas grasslands (Dyksterhuis and Schmutz, 3) showed that the total natural mulch was 1.2 times the amount of green herbage contributed annually. The data on native pastures in Kansas (Tomanek, 8) indicated that the amount of litter (mulch) varied from 0.29 to 1.01 times the unclipped herbage at the end of the growing season. Kelting's data (4) for Oklahoma grasslands, showed that the natural mulch was 1.2 to 4 times the annual production of green herbage: revegetating, abandoned field, 1.2; protected pasture, 2.9; virgin prairie, 3.8; and grazed pasture, 4.0. These reports suggest that the relative rates of accretion and decay of dead plant materials are similar in forests and grasslands. The data from Kelting (4) indicate that a balance between accumulation and decay of natural mulch has not been reached in the revegetating field. Just when this balance is finally reached during grassland succession is a problem for future investigation.

The relation between plant mulches and the amount of organic carbon in the soil has been the subject of much discussion. The U. S. Forest Service (9) stated that "on the virgin range, dead plants and herbage formed a ground litter and eventually mixed year after year with the mineral soil." Alderfer and Merkle (1) found that the organic content of the soil was greater at the end of the fourth year with surficial crop residues than when the crop residues were turned under. The differences (in per cent) were greatest at the 0-1 inch depth (3.72 vs. 2.71), less at the 1-3 inch level (3.11 vs. 2.89), and least at the 3-6 inch depth of (2.75 vs. 2.55). Aldous (2), however, suggested that the increases in soil organic matter, in Kansas pastures, were due to augmented root systems instead of a greater quantity of surficial, dead plant material. Kelting (4) found that the amount of organic carbon was related to the quantity of living plant material. He suggests that "with more living plant material above the ground, one would find more roots and hence more organic carbon in the soil." In the current investigation, the only increase in organic carbon occurred under the medium straw mulch, where mixing of mulch and soil was accomplished by earthworms, insects, and small mammals. It appears probable that increase in organic carbon in soils occurs largely through the decay of roots and the mixing of mulch and mineral soil by soil organisms.

Summary

Four mulch plots of one-sixteenth acre each were prepared by adding mulches to a revegetating field with a natural mulch of 4416 pounds per acre. The plot designations and total amounts of mulch (including the natural mulch) in pounds per acre, were as follows: medium straw, 7672; heavy straw, 15585; medium hay, 7270; and heavy hay, 11820.

During the first two growing seasons (1950, 1951) number of species, total areal cover, and oven-dry weight of green herbage were lower in the mulch plots (except in the medium straw plot) than in the control, and lower in the native hay units than in the oat straw plots.

In the two growing seasons, mulch decreased the ecesis of *Aristida oligantha* and *Leptoloma cognatum*, had no apparent effect on *Panicum scribnerianum*, and increased the establishment of the weedy forbs, *Aster ericoides* and *Ambrosia psilostachya*. Oat straw augmented, but native hay decreased, the ecesis of *Lespedeza stipulacea*.

Mulch had no apparent effect on hydrogen-ion concentration. The only effect on organic carbon in the soil was a slight increase under the medium straw mulch. The soil under the mulches was harder, and the volume weight values were slightly higher, during the first growing season. Soil moisture was greater in the mulch plots than in the control except under the medium straw mulch.

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