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Effects of Sawdust Mulches

I. Soil Properties

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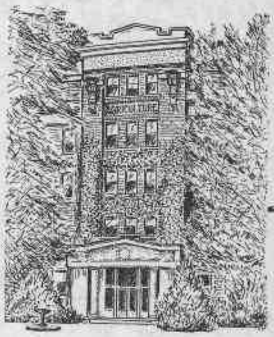

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This study is a summary of work carried out in connection with sub-project II of Project Adams 45 by the Department of Soils, Oregon Agricultural Experiment Station.

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Effects of Sawdust Mulches

I. Soil Properties

Introduction

Value of sawdust and other wood wastes as mulches or soil amendments has received considerable study. A need exists, however, for more complete information regarding effects of these materials on physical, chemical, and biological properties of soils to which they are added.

An extensive field trial was started at the Lewis-Brown Horticultural Farm in spring, 1949 with Marshall strawberries as an indicator crop to study effects of Douglas Fir sawdust, with and without fertilizers and applied both as surface mulch and incorporated with surface soil, on plant growth and soil properties.

Materials and Methods

The experiment was designed as a randomized block in split-plot design with four replications. Main treatments included: (1) sawdust applied as surface mulch in a layer 3 inches deep, (2) an equivalent amount of sawdust incorporated with the surface few inches of soil, and (3) clean cultivation or no sawdust. Sub-treatments superimposed on each of these three main treatments included nitrogen, phosphorus, and potassium applied as follows:

LBS. N-P_2O_5-K_2O APPLIED PER ACRE

Treatment Number	1948	1949	1950	1951
1	0–0–0	0–0–0	0–0–0	0–0–0
2	0–150–100	0–150–100	0–150–100	0–150–100
3	200–0–0	200–0–0	200–0–0	200–0–0
4	100–150–100	100–150–100	100–150–100	100–150–100
5	100–150–100	50–150–100	25–150–100	12–150–100
6	200–150–100	200–150–100	200–150–100	200–150–100
7	200–150–100	100–150–100	50–150–100	25–150–100
8	400–150–100	400–150–100	400–150–100	400–150–100
9	400–150–100	200–150–100	100–150–100	50–150–100

Ammonium sulfate, superphosphate and muriate of potash were used to supply nitrogen, phosphorus, and potassium respectively.

Strawberries became infested with red stele disease (*Phytophythora fragariae*) and were removed in 1952.

In spring, 1953 all plots were rotovated thoroughly, thus incorporating sawdust which had previously been applied as surface mulch. A sweet corn crop was used to study residual effects of sawdust and fertilizer treatments.

Sweet corn was planted following rotovation in spring, 1953. No fertilizer was applied to the corn. An extensive soil sampling was made just after corn plants were well established in early summer. Soil samples were obtained from depths of 0 to 5, 5 to 12, and 12 to 24 inches. Twelve borings composited from each plot of each replication constituted a sample. Samples were obtained from plots receiving cumulative amount of 0, 400, 800, and 1,600 pounds of actual nitrogen per acre over a 4-year period with constant amounts of phosphorus and potash.

Leaf tissue samples were taken at three dates during growing season: when plants were thinned, approximately half way through the season, and when plants reached silking stage. The middle one-third of the fourth leaf of the main stalk from 30 plants in each plot constituted a sample.

Yield data were obtained in summer, 1953 when plots were harvested.

Soil and plant samples were analyzed for nutrient levels by the Soil Testing Laboratory during winter, 1953-54. Soil reaction was determined with a glass electrode Beckman pH meter. Total nitrogen in soils and plant tissue was determined by the Kjeldahl procedure, while nitrate nitrogen in soils was measured in the water extract using the phenoldisulphonic acid procedure. Soil phosphorus was extracted with sodium bicarbonate after the method of Olson *et al.* (4) and determined colorimetrically using ammonium molybdate and stannous chloride. Plant phosphorus was determined in the same manner after wet digestion. Soil potassium was determined with the Beckman Model B spectrophotometer with flame attachment in the neutral normal ammonium acetate extract, while plant potassium was also measured in the flame photometer after wet ashing. Oxidizable organic matter in soils was determined by a modified Walkley-Black procedure (9). Total carbon in soils was determined as carbon dioxide evolved during dry combustion of the sample at 950° C. by the method described by Piper.

Results and Discussion

Data presented are for soil samples taken from the 0 to 5 inch depth.

Soil Reaction

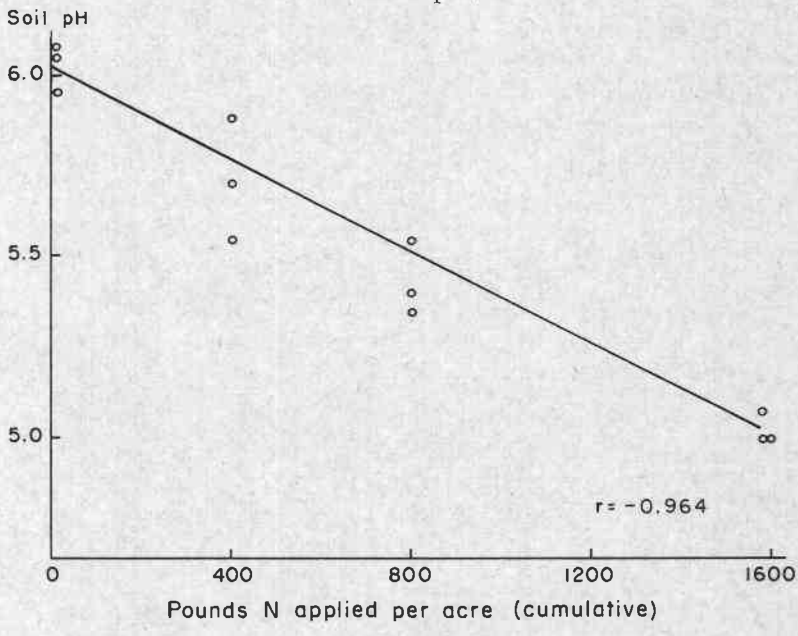
Application of nitrogen as ammonium sulfate reduced soil pH as the cumulative amount of nitrogen applied reached 1,600 lbs. per acre. Data are illustrated in Figure 1. Sawdust treatment had no effect on soil pH. Sawdust $\times$ nitrogen interaction was not significant.

Soil Nitrogen

Soil samples were analyzed for total nitrogen, for nitrate nitrogen prior to incubation of samples, and for nitrate nitrogen following incubation, or nitrifiable nitrogen.

Total nitrogen. Both sawdust and applied nitrogen significantly increased the amount of total soil nitrogen. Nitrogen $\times$ sawdust interaction was also significant. Incorporating sawdust with soil at the beginning of the experiment resulted in a greater relative increase in total nitrogen than occurred when sawdust was applied at

Figure 1. Effect of Nitrogen Applied as Ammonium Sulfate on Soil pH.



the beginning as a mulch and then incorporated 4 years later just prior to sampling. This can be attributed, perhaps, to more efficient utilization of nitrogen by microorganisms decomposing sawdust when it was incorporated in soil over a longer period of time. The data appear in Table 1.

Table 1. EFFECT OF SAWDUST AND NITROGEN ON TOTAL NITROGEN CONTENT (PERCENT) OF SOIL.

Sawdust treatment	Lbs. nitrogen applied per acre (cumulative)				Sawdust means
	0	*400*	*800*	*1,600*	
None	0.113	0.120	0.120	0.122	0.119
Incorporated (4 years previous)	0.123	0.132	0.133	0.145	0.133
Mulch incorporated (current season)	0.120	0.125	0.124	0.125	0.123
Nitrogen means	0.119	0.125	0.126	0.130	
L.S.D.	*.05*	*.01*			
Sawdust means	0.007	0.010			
Nitrogen means	0.003	0.005			
Individual means (interaction)	0.006	0.008			

Table 2. EFFECT OF SAWDUST AND NITROGEN ON WATER-SOLUBLE NITRATE-NITROGEN CONTENT (ppm N) OF SOIL BEFORE INCUBATION.

Sawdust treatment	Lbs. nitrogen applied per acre (cumulative)				Sawdust means
	0	*400*	*800*	*1,600*	
None	6.7	7.1	5.9	9.1	7.4
Incorporated (4 years previous)	3.0	3.1	3.3	5.6	3.7
Mulch incorporated (current season)	3.2	3.4	3.0	3.0	3.1
Nitrogen means	4.3	4.5	4.0	6.0	
L.S.D.	*.05*	*.01*			
Sawdust means	1.5	2.3			
Nitrogen means	1.6	2.1			
Individual means (interaction)	N.S.				

Table 3. EFFECT OF SAWDUST AND NITROGEN ON WATER-SOLUBLE NITRATE-NITROGEN CONTENT OF SOIL (ppm N) AFTER INCUBATION.

Sawdust treatment	Lbs. nitrogen applied per acre (cumulative)				Sawdust means
	0	*400*	*800*	*1,600*	
None	29.2	31.3	32.8	25.4	29.7
Incorporated (4 years previous)	24.2	34.1	31.3	22.9	28.1
Mulch incorporated (current season)	18.4	23.2	17.5	7.6	16.7
Nitrogen means	23.9	29.6	27.2	18.6	
L.S.D.	*.05*	*.01*			
Sawdust means	5.8	8.8			
Nitrogen means	3.3	4.4			
Individual means (interaction)	N.S.				

Pre-incubation nitrates. Sawdust treatment and applied nitrogen both affected water-soluble nitrate content of soil. Sawdust $\times$ nitrogen interaction was not significant. Sawdust significantly decreased nitrate content. This has been noted in previous similar studies (3, 8) and may be a reflection of denitrification which might have occurred in excessively moist and poorly aerated sawdust-treated plots. Plot area was irrigated at a uniform rate, and since irrigation had to be based on requirements of clean cultivated plots where evaporation and plant growth were greatest, sawdust-treated plots did not dry down between irrigations. The depressive effect of incorporated sawdust on nitrate level usually occurs when such highly carbonaceous material is added to soil.

Applied nitrogen increased nitrate content of soil when cumulative amount applied was 1,600 lbs. of nitrogen per acre but had less effect at lower rates.

Post-incubation nitrates. Both sawdust and applied nitrogen significantly affected soil level of nitrates after incubation (nitrifiable nitrogen). Sawdust $\times$ nitrogen interaction was not significant (Table 3). A comparison of sawdust means shows that the recently incorporated sawdust mulches depressed the level of nitrifiable nitrogen. This again may be a reflection of denitrification in these plots, resulting in reduction of ammonia and nitrate to elemental nitrogen and its subsequent loss through volatilization.

A comparison of nitrogen means shows an increase in nitrifiable nitrogen with a cumulative total of 400 lbs. of nitrogen per acre applied followed by a decrease as additional nitrogen is added, especially at the 1,600-lb. total. This can probably be attributed to effect of applied nitrogen in reducing soil pH shown in Figure 1. When 800 lbs. of nitrogen were added, soil pH was reduced to 5.43, and when 1,600 lbs. were added pH was reduced to 5.05. It seems that soil pH adversely affected the nitrifying bacteria and resulted in their reduced activity during incubation.

Available nitrogen (pre-incubation nitrates plus post-incubation nitrates). Effect of sawdust and nitrogen on available nitrogen content of soil, taken as the sum of nitrates before and after incubation, followed the same general trend as with post-incubation nitrates alone. Both were significant as indicated by data shown in Table 4. Sawdust $\times$ nitrogen interaction was also significant. Applied nitrogen had little effect in the absence of sawdust but had a pronounced effect where sawdust had recently been incorporated.

Soil Phosphorus

Sawdust incorporated into soil significantly decreased level of sodium bicarbonate-extractable phosphorus. Applied nitrogen had no effect. Sawdust $\times$ nitrogen interaction was not significant.

Individual treatment data shown in Table 5, although not significant, indicate an opposite effect of nitrogen in sawdust-treated and untreated plots. In clean cultivated plots, increasing applied nitrogen resulted in generally decreased soil phosphorus. In sawdust-treated plots, however, increasing applied nitrogen resulted in gen-

Table 4. Effect of Sawdust and Nitrogen on Content of Available Nitrogen (ppm N) in the Soil.

Sawdust treatment	Lbs. nitrogen applied per acre (cumulative)				Sawdust means
	0	*400*	*800*	*1,600*	
None	35.9	38.4	38.7	35.3	37.0
Incorporated (4 years previous)	27.1	37.2	34.6	28.5	31.9
Mulch incorporated (current season)	21.6	26.6	20.4	10.6	19.8
Nitrogen means	28.2	34.1	31.2	24.8	
L.S.D.	*.05*	*.01*			
Sawdust means	6.2	9.4			
Nitrogen means	3.6	4.8			
Individual means (interaction)	6.2	8.4			

erally increasing levels of soil phosphorus. An explanation may be that soil samples were obtained shortly following rotovation of plots. Level of inorganic phosphorus may have been higher because of increased solubility as a result of stimulated microbial activity and an accompanying increase of carbon dioxide in the soil.

Table 5. EFFECT OF SAWDUST AND APPLIED NITROGEN ON SODIUM BICARBONATE-EXTRACTABLE PHOSPHORUS (ppm P) IN SOIL

Sawdust treatment	Lbs. nitrogen applied per acre (cumulative)				Sawdust means
	0	*400*	*800*	*1,600*	
None	58.9	56.6	58.0	45.6	54.8
Incorporated (4 years previous)	36.1	45.6	43.3	46.7	42.9
Mulch incorporated (current season)	48.9	53.4	50.0	55.3	51.9
Nitrogen means	47.9	51.9	50.4	49.2	
L.S.D.	*.05*	*.01*			
Sawdust means	8.3	12.6			
Nitrogen means	N.S.				
Individual means (interaction)	N.S.				

Soil Potassium

Neither sawdust treatment nor applied nitrogen had a significant effect on the level of exchangeable soil potassium. Values ranged generally from 300 to 500 ppm potassium.

Soil Organic Matter

To determine organic matter soil samples were first ground to pass a 2mm sieve. A 10-gram sub-sample was then ground with mortar and pestle until it entirely passed a 0.5 mm sieve, after which a 0.5 gram aliquot was analyzed. These samples containing particles of undecomposed sawdust larger than 2mm may have shown values for organic matter lower than actually existed, assuming these particles contained oxidizable material and were sieved out during the first stage of sample preparation.

Sawdust treatment significantly increased the level of oxidizable organic matter. Applied nitrogen, however, had no significant effect. Sawdust $\times$ nitrogen interaction was significant. Sawdust had a greater effect when nitrogen was also applied (Table 6). Effect of added nitrogen on organic matter content is well illustrated in the sawdust-incorporated plots. Significance of sawdust $\times$ nitrogen inter-

Table 6. EFFECT OF SAWDUST AND NITROGEN ON CONTENT OF OXIDIZABLE ORGANIC MATTER (PERCENT) IN SOIL AS DETERMINED BY WET DIGESTION METHOD.

Sawdust treatment	Lbs. nitrogen applied per acre (cumulative)				Sawdust means
	0	*400*	*800*	*1,600*	
None	2.28	2.37	2.34	2.38	2.34
Incorporated (4 years previous)	3.04	3.51	3.64	3.75	3.49
Mulch incorporated (current season)	3.31	3.35	3.32	2.97	3.24
Nitrogen means	2.87	3.08	3.10	3.03	
L.S.D.	*.05*	*.01*			
Sawdust means	0.45	0.68			
Nitrogen means	N.S.				
Individual means (interaction)	0.37	0.50			

action is important since it illustrates importance of nitrogen in humification of highly carbonaceous organic material.

Soil Carbon

Some question exists on the exact meaning of values for soil organic matter obtained by determining organic carbon by wet digestion and use of an arbitrary factor. This arises because the proportion of carbon in soil organic matter may vary considerably, depending upon the stage of decomposition of the organic material itself, and also because soil organic matter may be oxidized to a different extent in different soil types. Reduced forms of iron and manganese in acid soils also complicate the problem since part of these may be oxidized during the wet digestion procedure and are included in the organic matter determination.

Determination of total carbon by dry combustion includes all organic carbon in the soil and does not distinguish forms. The determination also may fall short of expressing the amount of "active" organic matter in the soil. Soil carbon was determined by ashing a sample which had been ground in a hammer mill until it passed completely a 60-mesh sieve. An aliquot was taken for carbon analysis. By this preparation, all sawdust present in the sample was included regardless of particle size.

There is little likelihood that test values for organic carbon were modified by the preparation. Thus, values reported in Table 7 are considered to represent total organic carbon in all stages of decomposition, while those in Table 6 represent only a portion of organic

Table 7. EFFECT OF SAWDUST AND NITROGEN ON TOTAL CARBON CONTENT (PERCENT) OF SOIL AS DETERMINED BY DRY COMBUSTION METHOD.

Sawdust treatment	Lbs. nitrogen applied per acre (cumulative)				Sawdust means
	0	*400*	*800*	*1,600*	
None	1.40	1.46	1.48	1.47	1.45
Incorporated (4 years previous)	2.25	2.33	2.30	2.57	2.36
Mulch incorporated (current season)	2.72	2.84	2.70	2.48	2.68
Nitrogen means	2.12	2.21	2.16	2.17	
L.S.D.	*.05*	*.01*			
Sawdust means	0.28	0.37			
Nitrogen means	N.S.				
Individual means (interaction)	N.S.				

carbon and are quite likely modified to greater or lesser extent by sample preparation.

As might be expected, sawdust significantly increased total carbon content of the soil. The incorporation of the old surface mulches resulted in higher levels of soil carbon. This might be explained on basis of lack of intimate contact between soil and sawdust and a subsequently slower rate of decomposition and evolution of carbon as carbon dioxide. Applied nitrogen had no effect and the sawdust × nitrogen interaction was not significant (Table 7).

Plant Nitrogen

Leaf samples were analyzed for total nitrogen by the Kjeldahl procedure. The data appear in Table 8. Mean values are shown because of consistent trends across sampling dates. Sawdust significantly decreased nitrogen content of leaves, while nitrogen resulted in a significant increase at the 1,600-lbs. cumulative rate. Interaction was not significant. As could be expected, growth of sweet corn appeared closely correlated with nitrogen content, being superior on plots which received no sawdust.

Even though a cumulative total of 1,600-lbs. actual nitrogen per acre had been applied to some sawdust plots during the preceding 4 years, corn plants growing on plots which had a 4-year mulch incorporated just prior to planting exhibited poor growth and symptoms of severe nitrogen deficiency. Many plants never reached ma-

Table 8. EFFECT OF SAWDUST AND NITROGEN ON TOTAL NITROGEN CONTENT (PERCENT) OF CORN LEAVES. MEAN OF 3 SAMPLING DATES.

Sawdust treatment	Lbs. nitrogen applied per acre (cumulative)				Sawdust means
	0	*400*	*800*	*1,600*	
None	2.47	2.54	2.42	2.78	2.55
Incorporated (4 years previous)	2.13	2.28	2.20	2.34	2.24
Mulch incorporated (current season)	2.09	2.11	2.08	2.13	2.10
Nitrogen means	2.23	2.31	2.23	2.42	
L.S.D.	*.05*	*.01*			
Sawdust means		0.15	0.23		
Nitrogen means		0.11	0.15		
Individual means (interaction)	N.S.				

turity. This may be explained by one or more of the following considerations.

1. Since all plots were rotovated prior to planting corn, incorporation of highly carbonaceous sawdust may have stimulated microbial activity, thus causing depression of available nitrogen as normally follows incorporation of wide carbon-nitrogen ratio material.

2. Much of the nitrogen previously applied may have been lost through leaching resulting in lack of available forms. This is borne out by recovery of only 220 lbs. of total nitrogen where a cumulative total of 1,600 lbs. was applied (Table 1).

3. Since all plots were irrigated simultaneously with an equal amount of water, the sawdust treated plots, because of their higher moisture-holding capacity and lack of plant growth, remained in an almost saturated condition throughout the growing season. This constantly wet condition may have resulted in reduced plant growth due to excessive moisture, poor aeration, colder soil temperatures, impaired root development, and lack of available nitrogen as a result of denitrification. This latter suggestion appears to have some basis in the data of Table 4.

Plant Phosphorus

Sawdust treatment significantly increased percentage of phosphorus in corn leaves while applied nitrogen resulted in a significant decrease. Interaction was not sufficant. This response is probably a reflection of influence of sawdust and nitrogen on amount of plant growth. In other words, plants from sawdust-treated plots were in-

Table 9. EFFECT OF SAWDUST AND NITROGEN ON PHOSPHORUS CONTENT (PERCENT) OF CORN LEAVES. MEAN OF 3 SAMPLING DATES.

Sawdust treatment	Lbs. nitrogen applied per acre (cumulative)				Sawdust means
	0	*400*	*800*	*1,600*	
None	0.323	0.316	0.307	0.277	0.306
Incorporated (4 years previous)	0.482	0.398	0.403	0.315	0.399
Mulch incorporated (current season)	0.620	0.523	0.465	0.483	0.523
Nitrogen means	0.475	0.412	0.319	0.358	
L.S.D.	*.05*	*.01*			
Sawdust means	0.108	0.164			
Nitrogen means	0.051	0.069			
Individual means (interaction)	N.S.				

ferior in growth, and thus could be expected to contain a larger proportion of phosphorus. Plants receiving nitrogen were superior in growth and contained proportionally less phosphorus, showing effect of dilution. Nitrogen $\times$ sawdust interaction was not significant (Table 9).

Neither sawdust treatment or applied nitrogen had any effect on level of potassium in corn leaves.

Other Sawdust Studies

In 1950, studies not directly involved under Project Adams 45 were conducted with soil samples from plots which had received the following treatments:

1. Douglas Fir sawdust applied to a 3- to 4-inch layer and incorporated with soil in 1944 and renewed in 1947.
2. Alder sawdust applied and renewed in same manner.
3. Douglas Fir sawdust applied as a surface mulch in a 3- to 4-inch layer in 1947.
4. No sawdust.

Effects of treatment were determined on certain soil physical properties (Table 10).

Effects of sawdust on soil aggregation and moisture holding capacity agree with results reported by other workers (1, 3, 7, 8). Incorporation of sawdust increase useful moisture range of soil, but also reduced bulk density. Net result was little or no change in amount of water held by the soil.

Table 10. EFFECT OF SAWDUST TREATMENT ON CERTAIN PHYSICAL PROPERTIES AT SURFACE SOIL (0-4 INCHES) OF CHEHALIS CLAY LOAM.

Treatment	Organic matter content[1]	Useful moisture range[2]	Water stable aggregates 70.5mm[3]	Weight per cubic foot[4]	Non-Capillary porespace[5]
	Percent	*Percent*	*Percent*	*Pounds*	*Percent*
Untreated	2.68	13.5	11.0	89.9	7.2
Fir sawdust incorporated	6.72*	17.1*	41.7*	65.1*	26.5*
Fir sawdust mulch	2.19*	13.4	8.9	96.4*	2.4*
Alder sawdust incorporated	6.00*	17.0*	33.6*	67.0*	24.4*

* Significantly different from untreated plot.
[1] (9).
[2] Moisture equivalent minus 15 atmosphere percentage (2,5).
[3] As determined by wet seive method (6).
[4] Bulk density x 62.42. (Bulk density determined by weight of soil care of known volume).
[5] Total porespace minus capillary porespace.

Summary

As one phase of a study designed to show effects of sawdust on soil properties and plant growth an extensive field trial was initiated at the Lewis-Brown Horticultural Farm near Corvallis. Douglas Fir sawdust was applied, with and without fertilizers, both as a surface mulch and as a soil amendment to the surface soil. Marshall strawberries, used as the indicator crop, became infested with red stele disease (*Phytophthora fragariae*). Incidence of this disease was increased by both sawdust and nitrogen.

Following removal of the strawberries, all plots were rotovated and soil samples obtained. Sweet corn was planted to determine the residual effects of sawdust and fertilizer treatments.

Statistical analysis of data obtained showed:

1. Nitrogen applied as ammonium sulfate reduced soil pH as the cumulative amount of nitrogen applied reached 1,600 lbs. per acre over a 4-year period. Sawdust had no effect on soil pH.

2. Both sawdust and nitrogen increased total nitrogen content of the soil. Applied nitrogen had the greatest effect when sawdust was incorporated.

3. Water-soluble nitrates in the soil were decreased by sawdust treatment and increased by nitrogen treatment.

4. Both nitrifiable nitrogen (nitrates after incubation) and available nitrogen (nitrates before plus nitrates after incubation) in the soil

were decreased by sawdust and applied nitrogen. Sawdust had its greatest effect when recently incorporated.

5. Available soil phosphorus was decreased by sawdust treatment, but was not affected by applied nitrogen. Neither sawdust nor applied nitrogen had any effect on available soil potassium.

6. Oxidizable organic matter in the soil was increased by sawdust, but nitrogen had no effect. Sawdust had a greater effect when nitrogen was also applied. Results may have been modified by sample preparation.

7. Total carbon content of soil was increased by sawdust treatment.

8. Nitrogen content of corn leaves was decreased by sawdust and increased by applied nitrogen.

9. Phosphorus content of corn leaves was increased by sawdust and decreased by applied nitrogen. Leaf potassium was not affected by either sawdust or applied nitrogen.

In another study conducted to evaluate effects of Douglas Fir and Alder sawdust on certain soil physical properties, statistical analysis of data showed:

1. Incorporation of Fir and Alder sawdust increased content of oxidizable organic matter.

2. Soil aggregation, weight per cubic foot of soil, and non-capillary porespace were favorably affected by incorporation of Fir and Alder sawdust. Fir sawdust applied as a surface mulch had an opposite effect.

3. Useful moisture range in the top 4 inches of soil was increased by incorporation of Fir and Alder sawdust. Useful moisture capacity was not increased at the same time because of reduction in bulk density.

Observations carried on throughout these studies showed sawdust applied as a surface mulch facilitated such operations as weed control and harvest of strawberries. It also tended to reduce rate of moisture evaporation from soil surface and may have resulted in reducing conditions in the soil with too frequent irrigation.

Incorporated sawdust had a definite loosening effect on soil and also tended to retain soil moisture for longer periods between irrigations.

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