MISSOURI

AGRICULTURAL COLLEGE

EXPERIMENT STATION.

BULLETIN NO. 4.

A TEST OF TILLAGE IMPLEMENTS.

BY
J. W. SANBORN,
Director.

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MISSOURI AGRICULTURAL EXPERIMENT STATION,
Columbia, Boone County, Mo., Dec. 10, '88.

W. POPE YEAMAN, LL. D.,
President Board of Curators of University of Missouri, and Agricultural College:

SIR:—The Randall, Acme, spring teeth, square teeth, and smoothing harrows, Lubin pulverizer, the Albion, the Tower and the Eagle cultivators have been tested for draft, for depth of cultivation, for draft per inch and pound of soil-stirred and for pulverization of soil. These implements are those in use on the College farm and Experiment Station grounds, and represent several types of tillage implements. These are the Randall, with circular revolving plates with concave faces, turning at an angle to the track of the horse, and elevating and turning the dirt at one side and to the rear of the machine, in small ridges.

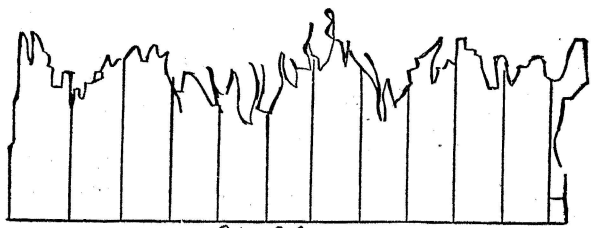
The Acme, with alternate winged cutting knives, whose faces are in opposite directions and therefore leave the earth level and also move the earth to the rear, and the Tower cultivator, with long cutting knives, set at an angle to the direction of the machine, and represent rear cut machines that lift the earth without at all tending to tear clods of earth up or to hook under obstructions. The spring teeth harrow,

the Albion harrow, and the teeth of the Lubin pulverizer, represent the front slanting teeth that lift the earth on their inclined planes and roll it to either side, burrowing often beneath the sods leaving them on the surface. The smoothing harrow with 64 round teeth, arranged to stand erect or slanting and the square teeth of the old fashion, but in a jointed harrow. And the Lubin pulverizer, designed to pulverize clods by projecting irons drill like at points, of 6 inches in length, surrounding a cylinder every 6 inches between which the spring teeth work, rolling out the clods to be broken under the spikes of the cylinder which is 16 inches in diameter, are wedges in principle moving the earth around them, but at the same time compressing it.

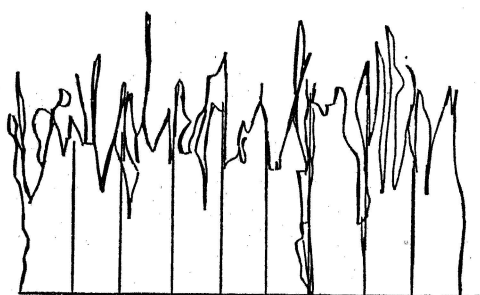
These implements were used upon four classes of soil, namely, an old grass sod, a soil for several years under tillage and somewhat lumpy from the influence of drought, corn ground from which stalks were removed at the roots for trial and tested before plowing and while in its compact state, and a clover sod.

The land is an upland clay loam. The Baldwin self-registering dynamometer was used as heretofore in wagon and plow trials reported in Bulletins 13 and 32.

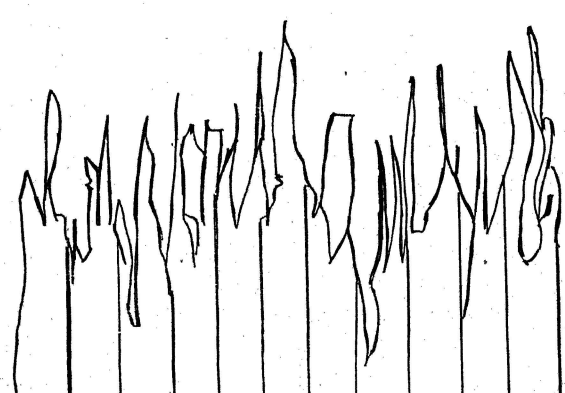
The accompanying cuts will show the draft of each implement for the second run on sod land. They are given to show the degree of steadiness of draft which varies with the implement, and also to show to the eye the relative draft of the several machines. The height of the wavy line above the straight line at the base of the cut marks the draft which is shown in the figures below, while the degree of irregularity of the upper line marks the unsteadiness of the running of the machine.



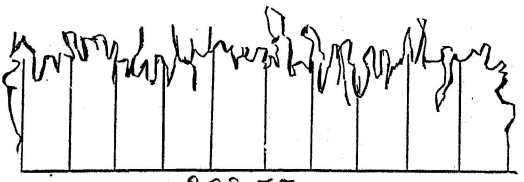
311.36
Acme



288.33
Randall

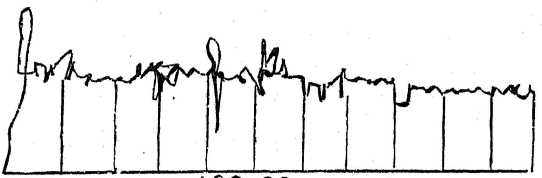


421.42
Lubin Pulverizer



208.75

Spring Toothed Harrow

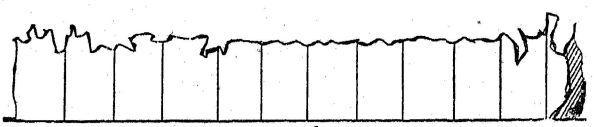


183.33

Smoothing Harrow
Teeth Straight

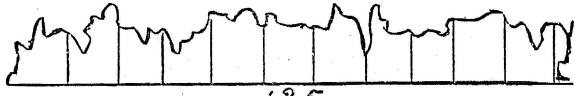
211.36

Square Toothed Harrow

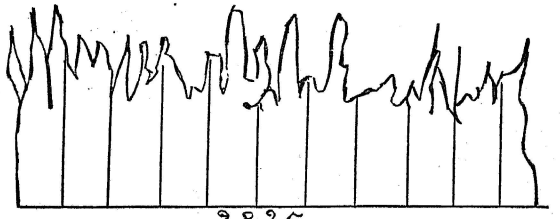


154.34

Golden Eagle



125.
Power Cultivator



282.5
Albion Cultivator

It will be observed that the Lubin pulverizer draws hard and is irregular in draft; the Randall harrow and Albion cultivator somewhat so, while the Acme moves more evenly and will, so far as this factor is concerned, worry the horses less than the above named machines.

The following tables are self-explanatory and reveal the purpose and scope of the trial. To relieve the reader of studying them unless he so desires, I will explain Table I. Three runs of the harrow were made, the draft being given in the first three columns and the average draft in the fourth column for the three runs. The width of the cut of the machine is given and its depth as a measure of the volume of earth stirred. The depth is ascertained by a large number of measurements of the earth loosened by each machine. The weight of the soil stirred was found by laying a frame two by three feet in the ground at three places where average work was done

and then carefully removing the earth moved by each machine. From these figures two facts were found, the weight of a cubic inch of soil and the weight of a cross section of the earth moved by each machine one inch wide to the depth cut. An end section of the soil stirred was calculated on the same principle that it is done for a plow trial, by multiplying the length by the depth in inches.

The earth removed by the frame above named was put through inch, half-inch, quarter-inch and thirtieth-inch sieves, to ascertain which machine pulverized the soil best—the chief end of tillage machines that follow plows, depth of tillage being considered.

A sixtieth-inch sieve was provided, but it was found so slow of use that it was abandoned, although its use is very desirable, and will be likely to accompany any further trials.

The primary design of the Albion cultivator, it is but fair to state, is the level cultivation of corn, but by inserting a middle section that accompanies it, it becomes a good riding spring teeth cultivator and seeder. In Table I. it is used as an ordinary after-plow tillage tool. Also the Lubin pulverizer is put upon the market as a combined tiller and pulverizer of clods.

TABLE I. TIMOTHY SOD—TWENTY YEARS STANDING.—THREE RUNS.

NAME OF MACHINE.	Draft of first run	Draft of second run	Draft of third run	Average draft of all runs	Width of machine—inches	Depth of soil stirred—inches	Weight per cubic inch of soil stirred—lbs.	Draft per square inch soil stirred	Draft per pound soil stirred	Amount of soil not passing through 1 inch mesh sieve		Amount of soil not passing through ½ inch mesh sieve		Amount of soil not passing through ¼ inch mesh sieve		Amount of soil not passing through 1-30 inch mesh sieve		Amount of soil passing through 1-30 inch mesh sieve		Per cent. of total draft of seven large machines	Draft per square inch stirred in one run
										lbs.	pr. ct	lbs.	pr. ct.	lbs.	pr. ct.	lbs.	pr. ct.	lbs.	pr. ct.		
Randall Harrow	318	288	298	301.7	70	2.71	.023	1.60	69.4	19.5	8.9	21.25	9.7	20.	9.01	46.9	21.3	112.1	51.05	15.31	6.40
Spring Tooth Harrow	214	209	238	220	72	1.87	.023	1.60	97.6	18.75	12.67	14.50	9.8	14.25	9.63	34.8	23.5	65.7	44.4	11.17	6.40
Acme Pulverizer	339	311	258	303	64	1.48	.025	3.20	128.	7.25	5.57	12.	9.2[illegible]	11.75	9.02	35.7	28.17	62.55	48.02	15.39	12.80
Albion	312	282	307	300	58	1.75	.031	2.96	95.8	22.75	12.13	16.25	8.6	18.	9.6	37.3	19.89	93.2	49.7[illegible]	15.40	11.84
Lubin Pulverizer	476	421	408	435	55	2.07	.030	3.80	127.6	13.75	6.39	18.25	8.4[illegible]	16.25	7.55	46.8	21.76	119.95	55.79	21.58	15.20
Smoothing Harrow—Teeth s't	220	183	183	196	102	1.60	.028	1.20	43.	17.75	11.37	16.75	10.7	12.75	8.17	49.8	31.92	58.95	37.78	9.9[illegible]	4.80
Square Tooth Harrow	227	211	204	214	80	1.59	.030	1.70	56.	15.50	9.35	19.00	11.4	17 00	10.25	45.8	27.63	68.45	41.29	10.86	6.80
Tower's Cultivator	187	150	147	161	48	1.03	.021	2.60	123.	13.00	13.57	8.50	8.8[illegible]	10.00	10.44	25.90	27.04	38.35	40.05	.....	.....

The order of draft of the above machines, leaving out the Tower corn cultivator, as out of place, passing from the lightest to the heaviest draft, is smoothing harrow, square-toothed harrow, spring-toothed harrow, Albion, Randall, Acme and Lubin, for absolute draft.

The depth of cut, an important factor, is as follows, passing from the deepest cut to the shallowest, Randall, Lubin, spring-toothed, Albion, smoothing, square-toothed and Acme tillers.

The Acme, Lubin and smoothing harrows left the best surface, and the spring-toothed, Albion and Randall harrows the poorest, the last one ridging the soil and the two previous rooting out the turfs in great freedom.

In weight per cubic inch of soil stirred the order is from the lightest to the heaviest soil left—a most important factor — Randall and spring-toothed, Acme, smoothing, Lubin and square-toothed and Albion tillers.

In draft per pound of soil stirred the real test of draft, the order from lowest draft to highest is smoothing, square-toothed, Randall, Albion, spring-toothed, Lubin and Acme.

In pulverization the order for surface fining is, Acme, Lubin, Randall, square-toothed, smoothing, Albion and spring-toothed tillers.

The largest per cent. of soil passing through a thirtieth-inch sieve was in the following order: Lubin, Randall, Albion, Acme, spring-toothed, square-toothed and smoothing tillers.

It will be seen that nearly all of the machines have a merit after their sort. This will be more plainly seen by noticing their changing places on the

different soils, as seen in Tables II., III., and IV. The conditions are so complex that I will offer no suggestions under the following tables, as it would result in a document too wordy for the closer logic of the exchequer, which is very sensitive to the influence of long bulletins and big mailing lists. I will suggest in this connection that inasmuch as the United States franks the bulletins and it is as essential to give them a wide circulation as to produce them, that our state print them in order that they may go into every school district of the state. This cannot be done with the present resources of the station without curtailing very seriously the work blocked out and essential to be done.

At the close of the tables I will attempt to generalize upon the results as a whole.

TABLE II. TWO RUNS OF MACHINE ON PLOWED CORN GROUND.

Name of Machine.	Draft of first run	Draft of second run	Average of both runs	Width of machine—inches.	Depth of soil stirred—inches.	Weight per cubic inch of soil stirred—lbs.	Draft per square inch of soil stirred	Draft per pound soil stirred.	Amount of soil not passing through 1 inch mesh sieve		Amount of soil not passing through 1/8 inch mesh sieve		Amount of soil not passing through 1/4 inch mesh sieve		Amount of soil not passing through 1-30 inch mesh sieve		Amount of soil passing through 1-30 inch mesh sieve		Per cent. of draft of each to total draft of all large machines	Draft per square inch stirred in one run
									lbs.	pr. ct.	lbs.	pr. ct.	lbs.	pr. ct.	lbs.	pr. ct.	lbs.	pr. ct.		
Randall Harrow	364	342	352	70	3.37	.016	1.50	93.5	34.00	24.63	19.50	14.13	13.05	9.78	22.00	15.94	49.00	35.50	16.78	3.00
Spring Tooth Harrow	218	219	218.5	72	2.45	.021	1.23	59.	40.50	29.94	18.25	13.49	11.75	8.64	19.75	14.62	45.00	33.27	10.72	2.46
Acme Pulverizer	326	266	296	64	2.14	.016	2.16	135.	16.25	18.36	10.75	12.14	8.75	9.88	15.25	17.23	37.50	42.37	14.53	4.32
Albion	376	257	317	58	2.53	.029	2.15	74.	76.00	29.68	31.00	12.10	21.00	8.20	31.70	12.38	96.30	37.61	15.07	2.15
Lubin Pulverizer	433	377	405	55	3.08	.017	2.40	140.6	30.50	22.67	14.75	10.96	12.25	9.10	23.50	17.47	53.50	39.77	19.87	4.80
Smoothing Harrow—Teeth str'i'gt	236	223	230	102	2.36	.025	.95	95.7	35.50	22.68	17.50	11.18	14.50	9.26	26.40	16.86	62.60	40.00	11.29	1.90
Square Tooth Harrow	243	195	219	80	1.88	.027	1.45	54.	37.00	28.03	14.50	10.98	11.00	8.33	15.40	11.66	54.10	40.98	10.74	2.90
Tower's Cultivator	205	145	175	48	2.98	.017	1.22	72.	49.00	36.91	15.00	11.29	10.25	7.72	18.70	14.16	39.80	29.98	......	......
Golden Eagle Cultivator	171	155	163	42	2.86	.018	1.35	75.	45.00	38.49	15.50	13.25	9.75	8.33	15.40	13.17	31.35	26.71	......	......
Albion as Cultivator	278	257	268	42	2.25	.019	2.80	149.	34.75	30.68	13.00	11.48	9.00	7.95	18.20	16.07	38.30	33.82	......	......
Smoothing Harrow—Teeth sla'ti'g	173	156	164	102	1.36	.025	1.20	47.	32.00	36.68	14.50	16.62	7.75	8.88	12.25	13.93	20.75	23.77	......	......
No machine	....	....	......	....	....	....	....	......	75.75	74.81	7.50	7.41	3.50	3.45	4.50	4.44	10.00	9.86	......	......

TABLE III. UNPLOWED CORN GROUND—FOUR RUNS.

Name of Machine.	Draft of first run	Draft of fourth run	Average of first and fourth runs	Width of machine—inches.	Depth of soil stirred—inches	Weight per cubic inch of soil stirred—lbs.	Draft per square inch of soil stirred	Draft per pound soil stirred	Amount of soil not passing through 1 inch mesh sieve		Amount of soil not passing through ½ inch mesh sieve		Amount of soil not passing through ¼ inch mesh sieve		Amount of soil not passing through 1-30 inch mesh sieve		Amount of soil passing through 1-30 inch mesh sieve		Per cent. of total draft of seven heavy machines	Draft per square inch stirred in one run
									lbs.	pr. ct.	lbs.	pr. ct.	lbs.	pr. ct.	lbs.	pr. ct.	lbs.	pr. ct.		
Randall Harrow	250	213	231	70	2.33	.022	1.41	64.	10.50	7.73	13.75	10.13	16.25	11.94	24.10	17.71	71.15	52.41	14.18	5.64
Acme Pulverizer	357	332	344	64	1.45	.023	3.70	161.6	3.00	3.38	5.50	6.19	9.25	10.42	17.70	19.94	53.36	60.06	20.50	14.80
Lubin Pulverizer	209	286	247	55	2.06	.019	2.17	91.	7.00	5.41	14.25	11.03	15.00	11.60	24.50	18.95	68.50	53.00	15.16	8.68
Albion	232	167	199	58	2.61	.034	1.30	38.7	19.50	8.38	20.50	8.81	25.00	10.74	40.30	17.33	127.45	54.76	11.62	5.20
Spring Tooth Harrow	264	202	233	72	1.51	.028	2.14	73.	5.25	4.74	11.00	9.85	12.25	11.06	20.00	18.06	62.25	56.21	14.31	8.56
Square Tooth Harrow	200	140	170	80	.99	.032	2.14	66.9	6.25	7.71	8.00	9.88	10.00	12.34	16.30	20.12	40.45	49.94	10.43	8.56
Smoothing Harrow—Teeth str'i'gt	[illegible]	182	205	102	.81	.035	2.50	70.5	5.75	7.92	7.75	10.69	8.00	11.03	15.00	20.69	36.00	49.66	12.59	10.00
Smoothing Harrow—Teeth sla'ti'g	140	164	152	102	.80	.025	1.90	74.	1.25	2.38	5.25	10.00	6.25	11.90	11.00	29.95	28.75	54.76	.....	....
Albion as Cultivator	255	182	218	42	2.18	.028	1.70	84.6	20.00	12.03	20.50	12.33	23.00	13.85	25.20	15.09	77.65	46.71	... .	.....
Golden Eagle	....	....	......	....	....	....	....	. .	6.	4.70	10.	7.84	10.7	8.33	29.5	23.10	71.50	55.99	.....	.....
Towers' Cultivator	163	125	144	48	1.25	.049	2.40	49.	10.75	6.72	13.25	8.28	17.00	10.62	26.70	16.56	92.30	51.44	.....	.....

TABLE IV. CLOVER SOD—FOUR RUNS.

NAME OF MACHINE.	Draft of first run	Draft of fourth run	Average draft of first and fourth runs	Width of machine—inches.	Depth of soil stirred—inches	Weight per cubic inch of soil stirred—lbs.	Draft per square inch of soil stirred	Draft per pound soil stirred.	Amount of soil not passing through 1 inch mesh sieve (lbs.)	Amount of soil not passing through 1 inch mesh sieve (pr. ct.)	Amount of soil not passing through ½ inch mesh sieve (lbs.)	Amount of soil not passing through ½ inch mesh sieve (pr. ct.)	Amount of soil not passing through ¼ inch mesh sieve (lbs.)	Amount of soil not passing through ¼ inch mesh sieve (pr. ct.)	Amount of soil not passing through 1-30 inch mesh seive (lbs.)	Amount of soil not passing through 1-30 inch mesh seive (pr. ct.)	Amount of soil passing through 1-30 inch mesh sieve (lbs.)	Amount of soil passing through 1-30 inch mesh sieve (pr. ct.)	Per cent. of total draft of large machines	Draft per square stirred in one run
Acme Pulverizer	367	382	374	64	1.55	.022	3.80	171.6	3.25	3.75	7.25	8.38	10.25	11.85	16.75	19.36	49.00	56.53	18.88	15.20
Randall Harrow	339	325	332	70	1.77	.018	2.70	148.7	11.50	13.77	9.50	11.38	11.00	13.17	13.00	15.57	38.50	46.11	16.76	10.80
Albion	293	226	260	58	1.50	.025	2.98	119.6	12.00	12.28	9.00	9.21	11.25	11.51	16.75	17.13	48.75	49.87	13.12	11.92
Spring Tooth Harrow	230	220	225	72	1.32	.032	2.40	74.	21.00	19.62	12.00	11.21	11.75	10.98	15.25	14.25	47.00	43.92	11.36	9.60
Lubin Pulverizer	364	333	348	55	1.67	.027	3.30	140.	6.00	5.08	10.75	9.09	13.75	11.62	23.80	20.04	63.95	54.09	17.56	14.20
Smoothing Harrow—Teeth stri'g't	269	214	242	102	1.02	.034	2.80	68.	13.25	14.80	10.00	11.16	9.75	10.39	13.80	15.39	42.70	47.71	12.21	9.20
Square Tooth Harrow	220	180	200	80	1.05	.032	2.40	74.4	9.50	10.67	7.25	8.11	8.50	9.55	12.50	14.04	51.25	57.58	10.00	9.60

TABLE V. AVERAGE OF EACH MACHINE FOR ALL SOILS.

NAME OF MACHINE.	Average draft for all soils.	Average depth of soil stirred—inches.	Average weight per cubic inch of soil stirred—lbs.	Average draft per square inch soil stirred.	Average draft per pound soil stirred.	Average amount of soil not passing through 1 inch mesh sieve for all soils		Average amount of soil not passing through ½ inch mesh sieve for all soils		Average amount of soil not passing through ¼ inch mesh sieve for all soils		Average amount of soil not passing through 1-30 inch mesh sieve for all soils		Average amount of soil passing through 1-30 inch mesh sieve for all soils		Average per cent. of draft of each machine to total draft of large machines.	Average draft per square inch turned in one run
						lbs.	pr. ct.	lbs.	pr. ct.	lbs.	pr. ct.	lbs.	pr. ct.	lbs.	pr. ct		
Randall Harrow	305	2.54	.020	1.83	99.60	18.87	13.15	16.00	11.33	15.07	10.97	26.50	17.63	67.68	46.29	15.76	6.46
Spring Tooth Harrow	224	1.79	.026	1.84	75.90	21.37	16.74	13.94	11.90	12.00	10.08	22.45	17.61	54.99	44.20	11.89	6.78
Acme Pulverizer	329	1.65	.021	3.21	149.	7.44	7.76	8.87	8.98	10.00	10.29	21.60	21.17	50.58	51.74	17.32	11.78
Albion	269	2.10	.029	2.34	82.02	32.56	15.62	19.19	9.69	18.81	10.01	31.51	16.68	91.42	47.98	13.80	7.78
Lubin	359	2.22	.024	3.04	124.80	14.31	9.89	14.50	9.89	14.31	9.97	29.65	19.55	76.97	50.64	18.54	10.72
Smoothing Harrow—Teeth straight	218	1.31	.030	1.74	69.30	18.06	14.19	13.00	10.94	11.25	12.33	20.25	21.21	50.06	43.85	11.51	6.47
Square Tooth Harrow	201	1.38	.030	1.92	62.82	17.06	13.94	12.18	10.11	11.62	10.11	22.50	18.36	53.56	47.44	10.51	6.96
*Tower's Cultivator	160	1.75	.029	2.07	81.33	24.25	19.07	12.25	9.46	12.42	9.59	23.77	19.25	56.82	40.49	......	......
†Albion as Cultivator	243	2.21	.023	2.25	116.80	27.37	21.35	16.75	11.90	16.00	5.90	21.70	15.58	57.97	40.26	......	......
*Smoothing Harrow—Teeth slanting	158	1.08	.025	1.55	60.50	16.62	19.53	9.87	13.32	7.00	10.39	11.62	21.94	24.75	39.26	......	......
†Golden Eagle Cultivator	162	2.14	.025	2.02	82.00	25.50	21.59	12.75	10.54	10.22	8.33	22:45	18.14	51.42	41.35	......	......

*Average of timothy sod, corn land and old ground.
†Average of old ground and corn land.

OBSERVATIONS.

The last column of Table V. shows that the lightest draft harrow draws thirty or more per cent. harder than the average draft of plow, as revealed in Bulletin 32, and over fifty per cent. harder than the necessary draft of the plow per square inch of end section of soil moved. The plow is a double wedge and therefore compresses the soil. It deals with masses and is an inverter of mass, while harrows and cultivators deal with particles and pulverize the soil, and must be expected to draw harder per square inch of soil moved. But the difference is not enough to warrant increasing the draft of the plow by making it a combined inverter and pulverizer of soil, as very convex mold boards are intended to be, so the figures seem to show.

How far do surface tillers become pulverizers?

Table II. shows that the plowed corn-ground at the opening of a drought had 74 3-4 per cent. of its first two inches in clods over one inch in size and that 9.86 per cent. of it only went through a thirtieth-inch sieve. After two harrowings with the Acme only 18.56 per cent. was in inch clods, while 42.37 per cent. passed through an inch sieve. The amount of the surface of the soil thus exposed to the disintegrating influence of the atmosphere, the capillary power of the soil, its power to hold moisture in its surface, its encouragement for the vein-like ramifications of roots, and the disappearance of drought killing cavities, the chief function of surface tillers, was very heavily enlarged. This coarse soil represents one of the more pronounced effects of surface

tillage. A fresh-turned soil will probably represent its other extreme. Indeed will pulverization take place on a fresh sod direct from nature's several dividing forces? A special trial of fresh-turned sod showed as seen in the following table a gain for tillage:

	Inch Clods. lbs.	Per cent. of total.	½-inch Clods. lbs.	Per cent. of total.	¼-inch Clods. lbs.	Per cent. of total.
Tilled Soil	2.93	9.73	2.22	7.37	3.97	13 19
Untilled Soil	10.81	26.23	4.25	10.31	5.16	15.52

	1-30-inch Clods. lbs.	Per cent. of total.	Less than 1-30-in. Clods. lbs.	Per cent. of total.
Tilled Soil	7.94	26.36	13.06	43.36
Untilled Soil	9.50	23.04	11.50	27.90

Tillage does fine a fresh soil and more than might be expected. It seems to reveal, when contrasted with the results on the clod land, the value of handling a soil when fresh turned as the fresh untilled soil shows much less lumps than the land for several days plowed. The soils cannot be satisfactorily compared as the corn ground had been for several years tilled while the other was a sod.

Tillage has been declared to be manuring, as it facilitates the access of air through increased porosity and thereby induces soil decomposition through increased fermentation and oxidation. Our figures show that tillage fines the soil. Does it thereby

increase the bulk and thus the air space? A two-inch gas pipe was driven into the ground on three trial sections many times just 1 1-2 inches. It was found that the weight of the untilled soil for a given bulk was 6.6 per cent. more than the tilled soil. Thus tillage increases the bulk or porosity of the soil while fining it.

COMPARATIVE EFFECT OF IMPLEMENTS.

No one implement excelled in all respects for all classes of soils, and illustrates the necessity of adapting machines to soil and purpose for which used. The relative draft fluctuates on the various soils as the last column but one shows, which points out the ratio of the draft of each machine to the total draft of all the machines compared, readily showing to the eye these variations. The Acme, for instance, shows 20 1-2 per cent. of the total draft of seven machines compared, when run on unplowed corn ground and a splendid relative pulverization, while on plowed, corn ground it required but 14.53 per cent. of total draft of all machines. On timothy sod its pulverization was less than three other machines, yet its average for all soils was the greatest. I should here explain that on this sod the Randall harrow was not quite as sharp as it should have been and was sharpened for the other soils. All other machines were in good order throughout. But the unsharpened Randall bea it on sod and fell behind on other soils.

Again, total draft cannot be our index of worth, for shallow tillers must necessarily run easier, as the deeper running machines have to, in going over the ground the second, third and fourth times, go

through a deeper layer of soil moved the previous time or times, in order to reach their work.

Regarding depth of tillage as one of the leading designs in tilling heavy soils and bearing in mind the point of relation of draft to depth made, the Randall harrow becomes a long way the leader of the Acme and Lubin pulverizers. The other machines draw easier per pound of earth moved, but at great sacrifice of depth and that will about balance the loss in draft if not overcome it. But column five of Table V. shows that the draft per square inch of soil turned, is less for the Randall (1.83 lbs.) than any harrow, save the surface tilling smoothing harrow (1.74 lbs.), or in other words, the Randall leaves the ground looser than the other machines save the Acme, which it greatly exceeds in other points named. But again, the Randall rolls the ground in ridges (cheaply leveled by a smoothing harrow) while on the other hand sod land is badly littered with turfs by the spring toothed harrows which neither the Randall nor Acme does.

But close inspection shows a variation on each soil, and on sod the Randall is in its glory, having the lightest draft of all of the machines, save the shallow tilling spiked harrows. Its pulverization is first, except the Lubin which shows its one single advantage here for this single soil. I therefore drop this machine out of further consideration. Its looseness of soil is first, or stands even with the Acme, being .023 lbs. per square inch. Its depth of cut 2.71 inches to the next best of 1.87 inches is a long way ahead. It stands easily first on sod.

As it is impossible to specialize in all of the details involved, I will summarize the advantages of each machine.

The Randall, or the disc harrow, appears to be the best all purpose machine, being particularly strong on sod land, draft, depth of cut, looseness of soil and pulverization. Ridging the land in the center of the machine being its one demerit, but this is cheaply leveled off by the wide, sweeping, smoothing harrow.

The Acme is first in pulverization, especially so on cloddy ground, it leaves the best top soil in evenness, and seems to be especially efficacious in its surface effects, as seen by the low per cent. of inch-clods it leaves, being 79 per cent. less than made by the Randall, while in the sub-area the Randall probably did the best, as its ratio of small clods was less than made by the Acme. It would seem to be an efficacious and very desirable machine for the first run over cloddy land.

THE SPRING-TOOTHED HARROWS. (*Walking and Albion.*)

They both have less draft than either of the above machines per pound of earth moved, but leave the earth more compact; having more draft per square inch of soil moved than the Randall, their depth is less although the Albion exceeds the Acme, but is not so deep cutting as the Randall by 25 per cent. The Albion gives slightly better pulverization than the Randall, but poorer on the surface by 13 per cent. so far as clods are concerned. They show best, especially the Albion, in draft, depth and pulverization, on the unplowed corn ground. It leads the Randall here.

This is the especial field of work for which the makers push it, as a level ground corn cultivator although it is convertable into a seeder and cultivator, where it is seen to do fairly well and very well in draft. For reasons soon to be given it can be commended for sandy soils.

The unplowed corn ground above spoken of, grew corn this year and had its stalk and roots carefully taken out for this trial. The idea involved was to test the question of the efficacy of surface tillers on eompact soil and fitness to supplant the plow on sodless ground.

A review of Table III.—the last column, will show that nothing is gained so far as saving of force is concerned. The average draft per square inch is 8.77, while the average draft of the plow per square inch is but 5.24. Substracting one from the 'other, it is found force enough is lost in harrowing before plowing, to plow first and harrow afterwards; the average draft by Table II. per run being 3.07, and the plow 5.24, a total of 8.3 1lbs.

THE SMOOTHING AND SQUARE TOOTHED HARROWS.

The smoothing harrow with teeth slanting, goes easier, shallower and leaves the soil looser than when straight, but does not fine it as well.

The square teeth go deeper, draw easier and fine the soil better than the round teeth set straight, while both draw easier than any other machine. Why not use them? Because they till shallow, and compact the soil. A cubic inch of soil, it is seen in the appropriate column, weighing 50 per cent more than after the

Randall and Acme harrows, the square teeth. Is there a place for these harrows? A look at their column of weight of soil per cubic inch, and a study of soils will reveal their place at once. They are wedges really compacting the soil and fairly fining it. Whenever it is desired to leave the surface a compact, fine soil pressing food and moisture around young and small seeds, they will do it while fining the soil. Again, all light and sandy soils want only surface tillage, and need compressing rather than loosening. The spring toothed harrows were shown to compress the soil and to go shallow. These are the places for these harrows.

This paper is so unexpectedly lengthy that I will not speak of the corn cultivators. I may refer to them and others in the future. The amount of work that they do is unexpectedly large, as compared with the heavier machines.

GENERAL NOTES.

The lifting out of all of the loose dirt made by each harrow revealed an interesting phase of harrows. The bottoms were extremely irregular. The Randall gave one of the worst corrugated bottoms of the list, being very sharply defined.

The Acme was much better and very fair, the Lubin good. The Albion was more imperfect than the other corn tillers and this will constitute its defect as a corn tiller, for if tillage is useful then we want it of as uniform depth as possible for obvious reasons. The smoothing harrow left the ground very nice and the

square toothed harrow next to it. This factor is an important one and manufacturers will have to turn their attention to it. A photograph taken of the bottom did not prove clear enough for use in the Bulletin.

Second. It will be noted that all of the tillers are more shallow in their action than they are supposed to be in the popular estimation.

Third. I would call attention to the fact that machines representing four principles were tried.

(*a*) *The revolving cutter.* This gave the greatest depth, loosest soil, and moderate draft, and a fine soil as a whole. It lifts the soil to the rear.

(*b*) *The rear cut or machine elevating the dirt to the rear.* This in the Acme gave a loose soil and finest tilth with a good bottom.

(*c*) Teeth with a forward slant leading the dirt up an inclined plane and pressing it in front. This gave a compacting influence, tore up turfs and did not fine the surface.

(*d*) *The wedge teeth.* Shallow tillers and soil compressors. It would appear that inventors should look for machines for the average soil that will turn the soil off to the rear with a lifting motion.

Fourth. H. J. Waters, B. A. S., a graduate of the Missouri Agricultural College, and for two years familiar with the experiment work of the farm by residence upon it and work in connection with it, and a very competent party had charge of the details of the trial, which were well executed.

Fifth. If any interested person feels that injustice has been done any one of the machines, the trial will be, so far as is necessary, repeated, with any machine that may be furnished for the purpose. Indeed, the Randall, Acme and Albion were tried over again since the previous portion of the Bulletin was written, and the results were fully confirmed, and a suggestion made in the early part of this Bulletin also verified, namely, that deep running machines, when contrasted with more shallow tillers in draft were put at a disadvantage when several runs are made. The Albion in this duplicate test on clover soil was run 1.89 inches to the Randall's 2 inches, and at these depths the Albion drew the harder of the two.

The Acme harrow was mounted on wheels.

REVIEW NOTES.

I. No one harrow is sufficient for the best tilth of a farm.

II. The harrow needed varies with the soil and its condition.

III. Harrows, as substitutes for plows, do not save force.

IV. Harrows till shallower than supposed.

V. The bottom of the tilled area varies widely in regularity.

VI. Wedge teeth and flat teeth with a front slant compress soil and are probably good for light soils.

VII. Teeth lifting dirt to the rear loosen soils best.

VIII. One harrow may break the clods best but not leave as much fine soil as another.

IX. Each harrow tried had a place to which it is best adapted, but for a general purpose harrow on a heavy soil, depth of cut, looseness of soil, ease of draft, and pulverization, being considered the leading demand of a harrow, the Randall, on the whole, proved the most satisfactory, although having the weakness of forming a bad bottom and of ridging the land. The Albion, being lighter of draft, proves a good machine, especially for the purpose for which it was designed.

Very respectfully,

J. W. SANBORN,

Director.