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by G. G. Pohlman and F. D. Cornell, Jr.

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Pasture Improvement In Upshur County

by G. G. Pohlman and F. D. Cornell, Jr.

In recognition of the importance of pastures in conservation and in West Virginia agriculture, the experimental Agricultural Conservation Program established in Upshur County in 1938 placed particular emphasis on pasture improvement. Previous investigations* in the state had shown that the low carrying capacity and the poor types of vegetation often present were associated with high acidity and low available phosphorus in the soils, and that the application of lime and superphosphate brought about both increase in yield and improvement in the quality of the herbage.† The emphasis in the experimental program therefore was placed on the application of lime and superphosphate. As a result a number of farmers treated part of their pasture acreages in 1938 and many others did likewise in the following years.

In order to measure the effect of the treatment on the carrying capacity of the pastures a cooperative project between the Bureau of Agricultural Economics and the West Virginia Agricultural Experiment Station was undertaken in the spring of 1940. The objectives of this experiment were:

1. To secure information from farmers regarding the effect of the treatment on the carrying capacity of their pastures, and the farmers' opinion regarding the value of such treatment.
2. To determine the effect of treatment on yield and quality of pasture herbage as measured by clipping.
3. To determine changes in vegetation resulting from treatment.

SELECTION OF FARMS

With the aid of the county agricultural agent and of the principal clerk of the Agricultural Conservation Program, farmers were selected who had carried out pasture improvement practices. The farms were visited and those having suitable areas were selected for further study. In determining suitable areas the following points were considered:

1. Treatments should consist of both lime and superphosphate applied to established pastures. (Both lime and superphosphate were to have been applied.)
2. An area of untreated pasture, in the same or adjoining pasture, having same soil, slope, exposure, and history should be available to serve as a check.
3. The treated and untreated areas should have been considered about equal by the farmer prior to treatment.

As a result of these limitations certain farms visited were considered unsuitable for tests. However, 24 treated areas were located in 1940 and 24 treated areas located in 1941.

* Pierre, W. H., Longwell, J. H., Robinson, R. R., Browning, G. M., McKeever, Ivan, and Copple, R. F. West Virginia Pastures: Type of Vegetation, Carrying Capacity and Soil Properties. W. Va. Agr. Exp. Sta. Bul. 280. 1937.

† Robinson, R. R., and Pierre, W. H. Response of Permanent Pastures to Lime and Fertilizers (1930 to 1936). W. Va. Agr. Exp. Sta. Bul 289. 1938.

PROCEDURE

After location of the pastures to be studied, three wire cages, four feet square, were located at random on each of the treated and untreated areas. The procedure on these areas was as follows:

(1) The caged areas were clipped regularly with a lawn mower and the clippings collected and their green weight determined.

(2) After thorough mixing, approximately 50 grams of the green sample was separated into (a) legumes, (b) grasses, and (c) weeds. Green weights of each of the above groups were determined to ascertain the relative proportion of each in the clipped pasture herbage.

(3) The clipped samples were dried and their dry weight obtained to determine the yield of grass.

(4) The dried grass samples were analyzed for protein content.

(5) Estimates of the relative areas of bare ground and of various kinds of vegetation were made twice during the pasture season.

(6) Soil samples were taken, for chemical analysis, from the area immediately surrounding each cage, representing two layers: the first, to 1½ inches depth and the second, from 1½ to 3 inches. Eight samples were taken at each depth.

(7) Soil samples were tested to determine the effect of treatment on soil reaction and on the content of available phosphorus.

Despite the care used in the selection of the areas, the results would be expected to be much more variable than those obtained under the usual methods followed in pasture experimental work for several reasons:

1. The rates of application of lime and fertilizers could only be estimated, since the treated areas were not measured and in many cases the amount of material applied was not weighed.

2. Much of the spreading was done by hand. This resulted in less uniformity of application than could have been secured by the use of machinery. Even when machinery was used there was the possibility of missing certain spots, especially with phosphate, since many of the rates of application were so low that the material did not show plainly on the ground and the tracks of the machines were the only way of determining treatment.

3. Since the treated areas were, in most cases, parts of larger pasture areas and in some cases the treatments were applied by persons other than the farmer, it was often difficult for the farmer to tell exactly where the outer limits of the treated area were.

4. Although the plots were selected at random within an area, the farmer's judgment regarding a comparable area was taken. It is difficult to remember the exact condition of small areas in a pasture, particularly after several years have elapsed, as was generally the case.

It was felt, however, that the information obtained would give results of value in showing what might be expected, on the average, from pasture treatment by farmers even though the results on a particular farm might not be a true indication of actual benefits which might be derived.

EXPERIMENTAL RESULTS

The study was carried on during the pasture seasons of 1940 and 1941. Because of seasonal variation and the location of plots on different farms in 1941, the results for these two seasons are discussed separately.

Experiments of 1940

Twenty-four treated areas were located during the month of May, and three wire cages were placed at random on each of the treated and untreated areas for test.

Pasture Treatment. The treatments applied to the 24 pasture areas are indicated in Table 1.

Burnt lime was used on 15 of the pastures at estimated rates varying from 500 to 2000 pounds per acre with an average of about 1247 pounds per acre. Ground limestone was used on nine of the pastures at rates varying from 1500 to 4000 pounds per acre with an average of 2167 pounds per acre. Triple superphosphate ($45\%P_2O_5$) was used on 17 pastures at rates of 100 to 250 pounds per acre with an average of 149 pounds. Ordinary superphosphate (20%) was used on seven pastures at rates varying from 150 to 500 pounds with an average of 293 pounds per acre. The materials used were furnished as grants-of-aid and probably represent the material that was available.

The acreage treated by the 21 farmers ranged from 1 to 40 acres, with an average of 11 acres per farm. Two-thirds of the farmers treated 5 acres or more. Most of the farmers selected had applied the lime and

TABLE 1 — *Rate of Treatment as Reported by Farmers, 1940*

Pasture No.	Lime		Phosphate		Year Treated
	Rate	Kind	Rate	Analysis	
	pounds		*pounds*	*percent*	
1	2000	Ground	150	20	1938
2	700	Burnt	250	20	1938
3	1000	Burnt	100	45	1938
4	2000	Ground	150	45	1938
5	2000	Ground	250	45	1938
6a	2000	Burnt	200	45	1938
6b	2000	Burnt	200	20	1939
7	1000	Burnt	200	45	1938
8	1500	Burnt	150	45	1938
9a	2000	Ground	500	20	1938
9b	2000	Ground	300	20	1939
10	1000	Burnt	150	45	1938
11	1500	Ground	100	45	1938
12	1000	Burnt	100	45	1938
13	2000	Ground	150	45	1938
14	1500	Burnt	250	20	1938
15	1000	Burnt	100	45	1938
16	1000	Burnt	100	45	1938
17	2000	Ground	400	20	1938
18	1500	Burnt	150	45	1938
19	4000	Burnt	150	45	1938
20	2000	Ground	175	45	1938
21a	1000	Burnt	150	45	1938
21b	500	Burnt	150	45	1939

superphosphate in 1938, but three had treated additional acreages in the same pasture in 1939. This accounts for the fact that, although there were only 21 farms, 24 treated pastures were included in the study.

Farmers' opinion of treatment. Each of the farmers who had treated pasture was asked to evaluate his pastures before and after treatment. The 15 farmers answering estimated the carrying capacity before treatment at from 3 to 6 acres per animal unit with an average of 4.2 acres. After treatment the carrying capacity was placed at from 1 to 4 acres with an average of 2.2 acres per animal unit. All but one of the farmers indicated an increase in carrying capacity as a result of treatment, the increases ranging from 33 to 300 percent. The average estimated increase in carrying capacity was 91 percent.

In addition the farmers were asked the question, "Do you think it pays to improve pastures?" All of the farmers said they thought it did, even though not all of them had indicated any gain in carrying capacity.

Effect of treatment in changing soil reaction and available phosphorus. The effect of the applications of lime and fertilizer on the soil reaction and available phosphorus content of the pasture soils is given in Table 2.

TABLE 2 — *Soil Reaction and Available Phosphorus of the Surface Layer to a Depth of 1½ Inches, and Yield of Treated and Untreated Areas, 1940*

Pasture No.	Reaction (0–1½")		Available Phosphorus (0–1½")		Yield		
	Untreated	Treated	Untreated	Treated	Untreated	Treated	Increase
	pH	*pH*	*ppm*	*ppm*	*grams*	*grams*	*percent*
			(Areas having inadequate treatment[1])				
1	5.17	6.03	7.2	8.3	120	122	2
4	5.21	5.61	17.1	22.0	130	132	2
5	5.43	5.46	6.0	7.0	117	166	42
6a	5.10	5.79	6.4	7.3	37	124	235
7	5.50	5.72	14.1	11.5	179	175	– 2
8	5.37	5.17	7.4	8.0	108	131	21
9a	5.43	5.35	6.2	9.8	107	126	18
9b	5.43	5.39	6.2	8.3	107	96	– 10
14	5.20	6.26	4.1	5.1	107	91	– 15
15	5.48	5.71	8.9	11.1	161	213	32
18	5.28	6.02	5.1	4.7	85	86	1
19	5.70	5.18	6.7	12.6	72	65	– 10
21b	5.35	5.81	8.5	9.6	106	120	13
Average	5.36	5.65	8.0	9.6	111	127	15
			(Areas having adequate treatment[2])				
2	4.95	5.76	4.4	11.0	39	68	74
3	5.73	6.38	5.5	21.3	126	216	71
6b	5.10	5.48	6.4	11.9	37	105	184
10	5.19	6.05	15.6	30.1	78	257	229
11	5.13	6.15	9.3	23.3	188	264	40
12	5.25	5.75	10.2	15.5	161	303	88
13	5.40	5.80	8.0	13.8	98	189	93
16	5.37	5.86	3.6	13.4	72	119	65
17	5.42	6.86	5.9	19.9	21	41	95
20	5.13	6.21	6.7	10.6	91	132	45
21a	5.35	5.71	8.5	20.2	106	127	20
Average	5.27	6.00	7.6	17.4	92	165	79
Average (all plots)	5.32	5.81	7.8	13.2	102	144	41

[1] Treated areas are not significantly higher in either pH or available phosphorus
[2] Treated areas are significantly higher in both pH and available phosphorus.

The plots are divided into two groups on the basis of the analysis of the treated area as compared with its check. Those areas in which the differences in either pH or available phosphorus are low and may be due merely to plot variation are indicated as areas having "inadequate treatment". Possible explanations of such variations have been offered previously.

The acidity of the untreated pasture areas ranged from pH 4.95 to pH 5.73, with an average of pH 5.32. All but two of the untreated areas were considerably below the desirable reaction for growth of bluegrass and clover and even the two with the highest reaction would be expected to respond to applications of lime. The reaction of the treated areas varied from pH 5.17 to pH 6.86, with an average of pH 5.81. If pH 5.8 is considered the minimum for optimum growth of bluegrass and white clover, as is usually the case, only 11 of the treated areas had sufficient lime to bring the reaction of the surface layer of soil (1½ inches) up to the proper level. In four of the treated areas the soils were more acid than in the check areas and in one of the others (Pasture 5) the difference (pH 0.03) was too small to be significant. In addition, the decrease in acidity on Pasture 4 was due entirely to one of the three areas, the two others being practically the same as the check areas. These are included in the group designated as having "inadequate treatment". This group shows an average increase of 0.29 pH units as a result of liming as compared to an increase of 0.73 pH units on those which had apparently received more uniform treatment.

The pH values for the 1½ to 3 inch layer were determined as a check on surface reaction and possible downward movement of lime on the treated areas. In the untreated areas this layer was usually slightly more acid than the surface layer. On the treated areas the acidity of the 1½ to 3 inch layer was usually about the same as that of the same layer on the untreated areas of the same pasture and considerably lower than that of the layer above. In only three cases (Pastures 10, 15, and 17) did there appear to be any significant movement of lime below the 1½ inch depth.

The available phosphorus content of the soils varied from 3.6 to 17.1 parts per million on the untreated areas, with an average of 7.8 parts and from 4.7 to 30.1 parts per million on the treated areas, with an average of 13.2. In two areas there appeared to be slightly less available phosphorus in the treated areas than in the untreated ones (7 and 18). In addition, pasture areas 1, 5, 6a, 8, 9b, 14, 15, and 21b showed increases in available phosphate of less than 3 parts per million. All of these are within the limits of error, especially when one considers the variations within the triplicate cages. In pasture area 4 the increase was due entirely to one sample, the other two being about the same as the check areas. It would appear, therefore, that the cages on these areas were not located where adequate uniform treatment had been made. The 11 areas in which both lime and phosphate treatments appeared to be well distributed showed an increase of 9.7 parts per million available phosphate as a result of treatment as compared to 5.4 parts per million increase for the entire group.

Yield of clipped herbage. The yield of grass for each area as measured by clipping with a lawn mower is also given in Table 2. The yields represent the total weight of dry grass in grams from five clippings unless otherwise indicated.

Before discussing the results, it should be pointed out that the yields are relatively low because of the late date at which the areas were located. The grazing season during which measurements were made averaged only 94 days, mostly in June, July, and August; thus the early spring and fall growth, which is usually most luxuriant, was not included and the results measure the growth during the hottest part of the summer when the pastures are usually relatively short.

The treated areas yielded, on the average, 41 percent more than the untreated areas. This amounts to 252 pounds per acre increase. Careful study of the data from the areas receiving "inadequate" and "adequate" treatments reveals the fact that, in most cases, the plots giving slight increases are the ones in which, according to soil analysis, the treated areas had not received adequate treatment. In these areas the increases varied from minus 15 to 235 percent, with an average of 15 percent. On the other hand the remaining areas which, judged from soil analyses, had received uniform applications of both lime and phosphate showed increases ranging from 20 percent to 229 percent, with an average of 79 percent for the 11 areas.

Composition of clipped herbage. The effect of treatment on the kinds of herbage clipped and on the protein content are given in Table 3. Here again the data are divided into two groups on the basis of change in chemical analysis of the soil.

The general averages show an increase in legumes and a slight decrease in both grasses and weeds. Although there were wide variations in individual plots, there was an increase in clover in all cases except Pastures 9b and 14. Both of these are grouped with those having "inadequate treatment". The increase in legume content was most marked in the plots receiving "adequate treatment" in which it was, on the average, from 0.8 to 24.9 percent of the weight of green herbage clipped.

In a large number of areas the decrease in relative proportion of grasses and weeds on the treated areas was due to the increased growth of legumes rather than to a decrease in the actual yields of grasses and weeds. Furthermore, it must be considered that these percentages are based on green weight and that legumes usually contain a higher percentage of water than do the grasses. Even if this is considered it would not change the general conclusion which must be drawn, namely, that treatment has influenced the legume content to a greater extent than it has either grasses or weeds.

The effect of treatment on protein content of the clipped herbage is also given in Table 3. In all but two cases, the treated areas were higher in protein content than the untreated areas. The increases were greatest on the plots indicated as receiving "adequate treatment", the

average increase in protein content for all plots being 3.3 percent. This was due largely to the increase in legumes, but some may have been the result of increased protein content of the grasses growing in association with the legumes. Regardless of the cause of the increase, the difference is great enough to be highly significant and indicates a better quality of pasture herbage on the treated areas.

Estimates of cover. Estimates of the type and kind of cover were made in the spring and fall in order to give additional information regarding changes in cover resulting from treatment. The average values for legumes, desirable grasses, danthonia and broomsedge, weeds and bare ground are given in Table 4.

Although these values are only estimates, and as such are subject to errors in judgment, they do help to show changes in the type of pasture herbage following treatment. The greatest change was in the legume content which showed an increase as a result of treatment in all areas except one. The effect was so marked that there is no question that the differences were greater than any possible error in judgment. White clover was the most abundant legume in most of the pastures, with smaller amounts of hop clover, sometimes common lespedeza and occasionally red or alsike clover. Furthermore, it is of interest to

TABLE 3 — *Effect of Soil Treatment on Botanical and Chemical Composition of the Clipped Herbage, 1940*

Pasture No.	Legumes		Grasses		Weeds		Protein Content	
	Untr'td.	Treated	Untr'td.	Treated	Untr'td.	Treated	Untr'td.	Treated
			(Areas having inadequate treatment)					
1	None	8.3	65.0	52.6	35.0	39.1	10.9	14.4
4	2.0	4.9	43.9	49.7	54.1	45.4	13.6	13.6
5	4.4	4.7	67.0	66.6	28.6	28.7	12.5	14.2
6a	None	11.3	58.1	48.9	41.9	39.8	9.6	12.5
7	0.6	9.1	56.7	49.4	42.7	41.5	17.2	17.9
8	0.5	10.7	81.7	81.9	17.8	7.4	12.8	13.5
9a	0.7	5.0	54.3	37.7	45.0	57.3	12.6	13.7
9b	0.7	None	54.3	57.0	45.0	43.0	12.6	11.9
14	None	None	84.9	82.4	15.1	17.6	10.3	11.2
15	7.9	25.3	62.4	48.9	29.7	25.8	12.6	16.9
18	None	0.1	68.5	61.9	31.5	38.0	13.9	13.2
19	1.4	12.4	39.3	48.1	59.3	39.5	14.7	16.3
21b	2.9	25.0	51.8	59.8	45.3	24.2	11.6	13.8
Average	1.6	9.0	60.6	56.6	37.8	34.4	13.0	14.4
			(Areas having adequate treatment)					
2	None	7.8	56.8	54.8	43.2	37.4	11.3	13.5
3	None	25.3	71.5	42.5	28.5	32.2	11.3	17.5
6b	None	2.8	58.1	62.5	41.9	34.7	9.6	11.1
10	None	60.3	57.7	22.9	42.3	16.8	12.2	20.2
11	3.0	41.2	59.2	43.2	37.8	15.6	14.1	21.7
12	3.1	15.3	46.9	53.4	50.0	31.3	14.7	18.7
13	None	7.5	61.7	55.1	38.3	37.5	11.7	12.6
16	None	10.8	82.4	70.4	17.6	18.8	11.0	13.8
17	None	34.7	66.2	48.5	33.8	16.8	11.3	20.5
20	None	30.3	81.4	48.9	18.6	20.8	10.7	16.3
21a	2.9	37.9	51.8	42.2	45.3	19.9	11.6	17.6
Average	0.8	24.9	63.1	49.5	36.1	25.6	12.4	17.5
Average (all plots)	1.3	16.3	61.7	53.3	37.0	30.4	12.7	16.0

note that the relative change in legumes for the individual areas was very similar to the changes reported from the sorted samples. Variations may be readily explained by the fact that the mere presence of a plant does not necessarily indicate that it will appear in the clippings, since some low growing plants will not be reached with a lawn mower but still will afford considerable cover. In addition it should be remembered that the sorted sample represents weighted averages of five clippings, whereas estimates were made only twice during the year.

The increase in desirable grasses was likewise quite marked in most of the treated areas, and in no case was any decrease observed. Direct comparisons with grasses and weeds in sorted samples are not possible since certain grasses such as foxtail, crab grass, etc., are considered as weeds. However, despite variations, it seems logical to assume that, since desirable grasses, as determined by estimates, increased with treatment, they would likewise be present in larger amounts in the clipped herbage.

As the legumes and desirable grasses increased the less desirable pasture plants such as broomsedge, danthonia, and weeds and the bare space tended to decrease. The decrease in bare space was most evident,

TABLE 4.—*Estimates of Percentage of Cover on Pastures, 1940*

Farm No.	Legumes		Desirable Grasses		Weeds*		Bare	
	Untr'td.	Treated	Untr'td.	Treated	Untr'td.	Treated	Untr'td.	Treated
			(Areas having inadequate treatment)					
1	None	8	None	16	46	44	54	32
4	2	7	3	11	53	48	42	34
5	6	4	3	21	53	40	38	35
6a	1	12	None	4	51	52	48	32
7	2	10	37	47	37	25	24	18
8	8	16	4	14	51	41	37	29
9a	2	5	None	3	53	59	45	33
9b	2	4	None	2	53	61	45	33
14	1	2	1	3	43	48	55	47
15	10	33	1	3	43	30	46	34
18	1	4	2	5	48	36	49	55
19	1	17	2	7	45	44	52	32
21b	2	13	2	2	60	51	36	34
Average	2.9	10.4	4.2	10.6	49.0	44.5	43.9	34.5
			(Areas having adequate treatment)					
2	None	13	None	8	51	38	49	41
3	1	27	None	11	57	41	42	21
6b	1	5	None	None	51	57	48	38
10	None	35	None	5	62	49	38	21
11	1	26	1	38	65	20	33	16
12	3	24	3	20	71	46	23	10
13	1	11	None	1	55	61	44	27
16	None	19	1	7	54	43	45	31
17	2	15	3	61	61	11	34	13
20	None	23	None	1	43	40	57	36
21a	2	24	2	15	60	34	36	27
Average	1.0	20.2	0.9	15.2	57.3	39.1	40.8	25.5
Average (all plots)	2.0	14.9	2.7	12.7	52.7	42.0	42.6	30.4

* Includes broomsedge and poverty grass.

especially on the plots receiving adequate treatment but occurred to some extent in all but one of the treated areas. Since cover is of utmost importance in erosion control, the reduction in bare space indicates that treatment has decreased erosion on these pastures.

Experiments of 1941

The experiment was continued in 1941 with the same general procedure. As a result of "inadequate" or additional treatment some of the farms studied in 1940 were discontinued and additional areas located to make a total of 24 pastures in the experiment. Because of the large number of areas which did not indicate uniform treatment the previous year, each area was checked for soil reaction and available phosphorus in the field before locating the cages, and only areas which showed reasonably uniform treatment were selected. On four of the farms the cages were moved so frequently by the cattle that reliable results were not secured.

Pasture Treatment. The treatment and soil analyses of the 20 areas for which data were secured are given in Table 5. Farm numbers 6a, 10, 11, 13, 16, 17, and 20 refer to farms and pastures used in 1940, but the cages were relocated in all cases.

Twelve of the 20 pastures included were treated with burnt lime at rates ranging from 1000 to 2500 pounds per acre, with an average of 1583 pounds per acre. Ground limestone was used on six areas at rates of 1500 to 2000 pounds per acre, with an average of 1917 pounds per acre. Two of the farmers applied marl at the rate of 1500 pounds per acre.

TABLE 5 — *Rate of Treatment as Reported by Farmers, 1941*

Pasture No.	Lime		Phosphate		Year Treated
	Rate	Kind	Rate	Kind	
	pounds		*pounds*	*percent*	
6a	2000	Burnt	200	45	1938
10	1000	Burnt	150	45	1938
11	1500	Ground	100	45	1938
13	2000	Ground	150	45	1938
16	1000	Burnt	100	45	1938
17	2000	Ground	400	20	1938
20	1000	Burnt	175	45	1938
22	1000	Burnt	200	16	1939
23	1500	Burnt	75	45	1938
24	1500	Burnt	250	45	1940*
25	2000	Burnt	250	45	1940
26	2000	Burnt	200	45	1939
27	2500	Burnt	320	20	1938
28	2000	Ground	300	20	1939
29	1500	Marl	300	20	1940
30	1500	Burnt	100	45	1939
31	2000	Burnt	200	45	1939
32	2000	Ground	400	45	1940*
33	1500	Marl	150	45	1939*
34	2000	Ground	200	45	1939

* Lime applied the previous fall.

Fifteen farmers applied 45 percent superphosphate at rates varying from 75 to 400 pounds per acre, with an average of 180 pounds. Ordinary 20 percent superphosphate was used on five of the areas at an average rate of 330 pounds per acre and one farmer applied 200 pounds of 16 percent superphosphate.

Comparison with the previous year's survey indicates in general slightly higher average rates of application. It will be noted that most of the new areas selected were treated in 1939 and 1940. The records of the Agricultural Adjustment Administration show a considerable increase in numbers of pastures treated in these years. Part of these increases may be attributed to better knowledge of the program and to observations of results of pasture treatment the previous year. The areas treated ranged from one to 30 acres, with an average of 8.45 per farm. This is slightly lower than the average for 1940 principally because one 40-acre pasture treated in 1940 was not included in 1941.

Farmers' opinion of treatment. The farmers were again asked to evaluate carrying capacity before and after treatment. Before treatment the estimates ranged from three to 7½ acres per animal unit, with an average of 4.12. After treatment the carrying capacity was estimated at from one to 4½ acres per unit, the average being 2.22 acres. All of the farmers giving data indicated an increase in carrying capacity ranging from 11 to 300 percent, the average being 86 percent.

As in the previous year, all of the farmers indicated that pasture treatment was a profitable investment. Some even went so far as to say it was the best investment they could make.

Effect of treatment on soil reaction and available phosphorus. The

TABLE 6.—*Reaction and Available Phosphorus of the Surface Layer to a Depth of 1½ Inches, and Yields of Treated and Untreated Areas, 1941*

Pasture No.	Reaction (0–1½")		Available Phosphorus (0–1½")		Yield		
	Untreated	Treated	Untreated	Treated	Untreated	Treated	Increase
	pH	*pH*	*ppm*	*ppm*	*grams*	*grams*	*percent*
6a	4.96	5.38	6.1	9.3	148	247	67
10	4.69	5.76	7.0	20.2	240	375	56
11	5.07	6.14	11.5	17.9	299	331	11
13	5.22	5.88	7.7	19.8	229	378	65
16	4.83	5.50	5.6	15.2	189	270	43
17	5.11	6.57	7.7	18.7	192	494	157
20	4.79	5.71	8.2	76.9	165	334	102
22	6.30	6.60	6.6	19.8	178	268	51
23	4.97	5.19	3.8	5.4	211	231	9
24	5.34	6.11	5.4	46.3	208	239	15
25	4.80	6.09	6.9	36.5	127	283	123
26 (1)	5.62	6.48	5.4	19.4	75	85	13
27	5.08	5.64	6.4	7.8	233	276	18
28	4.96	6.10	9.6	19.0	144	245	70
29	5.52	5.51	7.2	11.8	234	364	56
30	5.12	5.67	7.3	9.6	150	191	27
31	5.27	5.83	6.4	15.3	160	307	92
32 (2)	5.18	5.74	5.0	22.5	237	426	80
33	5.10	5.57	8.0	9.2	257	318	24
34	4.28	5.41	7.4	14.4	152	341	124
Average	5.11	5.84	7.0	20.8	191	300	57

(1) Two cuttings.
(2) Four cuttings.

effect of applications of lime and superphosphate on the soil reaction and available phosphorus content of the soil is shown in Table 6.

The acidity of the upper 1½ inch layer in the untreated pastures ranged from pH 4.28 to pH 6.30, with an average of pH 5.11, whereas the treated pastures showed a range of from pH 5.19 to pH 6.60, with an average of 5.84. It will be noted that there was an increase of more than 0.2 pH units in all areas except one, in which there was no significant difference. In spite of the evidence of liming as measured by change in acidity only nine of the 20 treated areas had sufficient lime to raise the pH to above 5.8. However, the increase in the others would be expected to influence the yield and composition of the herbage even though it was not sufficient for optimum growth.

The reaction of the 1½ to 3 inch layer of soil was usually slightly lower than that of the surface layer in the untreated areas and considerably lower in the treated ones. Evidence of downward movement was again noted in Pastures 10 and 17 and also in Pastures 22, 26, 27, 28 and 30. Even in these areas, however, the pH reading was in most cases only slightly higher than the reading in the same layer in the untreated area.

The available phosphorus content of the untreated areas showed less variation than the previous year, the range being from 3.8 to 11.5 parts per million, with an average of 7.0. Treatment raised the phosphorus content in all areas, the smallest increase being 1.2 parts per million on Pasture 33 and the greatest 68.7 on Pasture 20. The average increase was 13.8 parts per million. Because of the greater uniformity of the areas, differences of more than 1.5 parts per million are greater than differences that might be attributed to error. In other words, only two of the areas appeared not to have had enough phosphate application to affect the available phosphorus in the soil.

Yield of clipped herbage. The yield of herbage for each area is given in Table 6. The yields represent total weight of dry grass from five cuttings unless otherwise indicated. All but three of the areas selected (27, 29, and 33) had apparently received sufficiently uniform applications of lime and superphosphate to show changes in soil analyses.

Yields from the untreated pastures varied from 75 to 299 grams, with an average of 191 grams. These yields are, on the average, almost twice as high as those secured the previous year. A part of this can be accounted for by the longer season, as the cages were placed almost a month earlier and thus more of the early growth was included. However, even in 1941 only 160 days were included in the pasture season as compared to about 200 days in which cattle are kept on pasture in the county.

Yields on the treated plots were also higher, averaging 300 grams. This represents an increase of 109 grams or 57 percent over the untreated areas. In terms of pounds per acre this amounts to an increase of 654 pounds. If only the plots receiving uniform treatment are considered, the increase in yield was 720 pounds per acre, or 68 percent. This agrees quite closely with the 79 percent increase obtained in 1940.

Composition of clipped herbage. The effect of treatment on the protein content and the kind of herbage clipped is given in Table 7.

Again, the most evident effect is on the legume content of the herbage, the average percentage increasing from 2.3 percent of the green herbage on the untreated to 21.1 percent of the green herbage on the treated areas. Increases were evident in all plots, varying from 6.4 percent in Pasture 6a to 41.8 percent in Pasture 10. Accompanying the increases in legumes were general decreases in percentage of both grasses and weeds. This decrease was usually the result of the increased clover content rather than any decrease in total weight of grasses or weeds. Actually, in the majority of cases, the yield of both grasses and weeds was higher on the treated areas, indicating that the treatment had encouraged their growth but not as much as it had encouraged the growth of legumes.

The effect of the legumes on the protein content of the herbage is also shown in Table 7. As was expected, the areas which contained the greatest percentage of legumes were usually the highest in protein content. The weighted average shows 16.1 percent protein in the dry herbage from the treated areas, as compared to 11.4 percent from the untreated areas or an increase of 4.7 percent. Increases were evident in all pastures, the smallest being 0.4 percent on Pasture 30 and the largest increase 11.4 percent on Pasture 20.

Estimates of cover. The field estimates of amount and kind of cover on the pasture areas in 1941 are given in Table 8.

In general the results are similar to those secured in 1940. On the treated areas 71.7 percent of the ground was covered with vegetation as compared to 49.0 percent on the untreated areas. More than one-half

TABLE 7 — *Effect of Soil Treatment on the Botanical and Chemical Composition of the Clipped Herbage, 1941*

Pasture No.	Legumes		Grasses		Weeds		Protein Content	
	Untr'td.	Treated	Untr'td.	Treated	Untr'td.	Treated	Untr'td.	Treated
6a	.9	7.3	63.4	60.6	35.7	32.1	9.8	12.1
10	.6	42.4	78.2	45.5	21.2	12.1	11.1	17.1
11	2.1	20.2	67.9	55.0	30.0	24.8	11.3	18.1
13	3.1	19.3	74.7	61.5	22.2	19.2	11.5	15.1
16	.2	12.1	78.2	73.3	21.6	14.6	9.2	12.4
17	1.9	12.1	70.5	70.9	27.6	17.0	11.5	19.1
20	.1	36.4	78.0	43.5	21.9	20.1	7.8	19.2
22	11.7	26.5	47.4	53.3	40.9	20.2	12.8	16.5
23	.4	10.4	81.7	67.5	17.9	22.1	9.6	11.9
24	.3	25.4	76.3	43.5	23.4	31.1	12.0	14.9
25	5.7	15.4	73.2	59.9	21.1	24.7	12.9	16.2
26	11.5	21.7	56.8	53.2	31.7	25.1	15.7	19.1
27	.3	12.7	40.5	58.6	59.2	28.7	12.8	14.0
28	4.0	15.7	64.2	62.3	31.8	22.0	12.5	16.6
29	2.4	30.7	43.5	42.1	54.1	27.2	14.2	17.4
30	0.1	8.1	60.7	62.8	39.2	29.1	12.2	12.6
31	.2	24.1	63.5	38.2	36.3	37.7	10.7	16.6
32	3.1	27.5	65.8	49.6	31.1	22.9	11.5	16.2
33	1.5	13.4	82.8	52.8	15.7	33.8	10.8	13.7
34	2.0	26.0	56.5	45.2	41.5	28.8	12.3	18.7
Weighted Average	2.3	21.1	66.7	54.8	31.0	24.1	11.4	16.1

of the vegetation on the treated areas consisted of legumes and desirable grasses, whereas only about 7 percent of the vegetation on the untreated areas was of a desirable type. The results of estimate of legumes confirm the finding for the sorted samples reported in Table 7. The results also show that, although the relative amounts of grass in the green sample had decreased, a larger part of the grass present consisted of the better pasture grasses. This better quality feed would be expected to give the pasture a higher carrying capacity over and above that which resulted merely from increase in total yield. In addition, the better cover would certainly reduce losses by erosion.

Distribution of Increased Yield Over the Grazing Season

The data presented thus far have dealt only with the averages over the grazing season. Such data have been criticized by some who have suggested that most of the increase was obtained during the early part of the grazing season when pasture is most abundant and that little increase resulted during the hot summer months. Inasmuch as the yields were taken at approximately monthly intervals, it is possible to make comparisons of average yields by months. These are given in Figures 1 and 2.

In both years the highest total yields were obtained during the early part of the grazing season. The smallest increase in 1940 on the areas designated as receiving adequate treatment was 52 percent during the month of August, and the highest was 84 percent during July. In 1941 the percentage increase became higher as the season progressed, being 29 percent in May and 78 percent in September.

TABLE 8.—*Estimates of Percentage of Cover on Pastures, 1941*

Pasture No.	Legumes		Desirable Grasses		Weeds*		Bare	
	Untr'td.	Treated	Untr'td.	Treated	Untr'td.	Treated	Untr'td.	Treated
6a	2	7	None	5	49	49	49	39
10	1	38	None	8	56	37	43	17
11	2	17	Trace	36	44	25	54	22
13	3	16	Trace	4	53	64	44	16
16	Trace	13	1	11	54	35	45	38
17	2	29	1	55	57	12	40	4
20	Trace	48	None	21	45	18	55	13
22	8	22	1	10	40	42	51	26
23	1	9	None	Trace	41	45	58	46
24	None	24	None	None	47	37	53	39
25	1	13	2	28	47	36	50	22
26	3	22	10	28	39	18	48	32
27	None	12	Trace	11	38	37	62	40
28	1	14	2	21	44	35	53	30
29	3	38	1	6	52	43	44	13
30	7	7	2	3	35	42	56	48
31	1	39	None	11	39	30	60	20
32	3	36	2	8	38	28	57	28
33	4	15	Trace	3	56	44	40	38
34	1	15	Trace	23	42	29	57	33
Average	2.1	21.7	1.1	14.7	45.8	35.3	51.0	28.3

* Includes broomsedge and poverty grass.

The relatively low increase in yield on the treated areas during May, 1941, was largely the result of close grazing on these areas the previous fall or early spring; in some instances the treated areas were grazed so closely that yields were very low for the first cutting.

Although these values were obtained by calculation from the clipped yields, they do indicate that, in the pastures studied, during 1940 and 1941, the increases in yield due to treatment were the result of increases throughout the entire growing season and not merely the result of increased flush growth during the spring and fall.

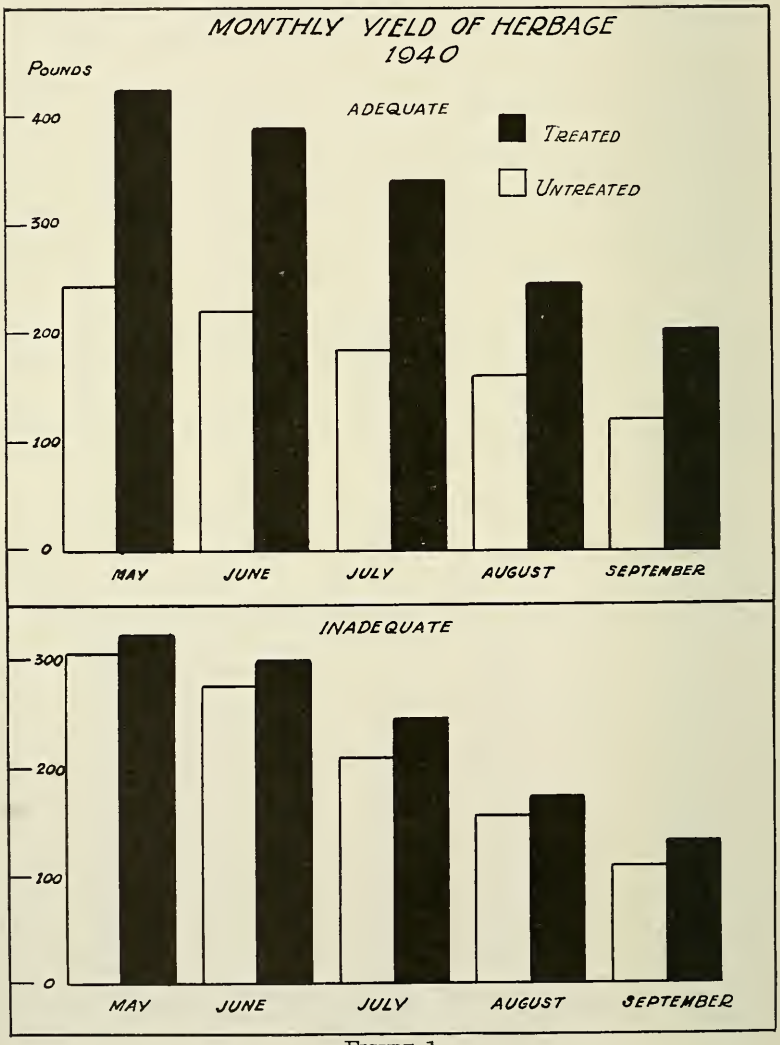

FIGURE 1

DISCUSSION

The foregoing data have demonstrated the increases in yield and quality of pasture as a result of application of lime and superphosphate. In order properly to evaluate pasture treatment, the cost of treatment must be compared with the value of the increased yield. Unfortunately, no single method is entirely satisfactory for making such a comparison.

The cost of materials and application will vary, depending upon freight and hauling charges and labor needed for application. Since most of the lime was applied as burnt lime at average rates of 1247 and 1750 pounds per acre on the pastures studied in 1940 and 1941 respectively, the cost of this material at $5.00 per ton would be $3.12 and $4.37 per acre. The cost of triple superphosphate per acre at $45.00 per ton would be $3.35 and $4.05 for the 1940 and 1941 areas respectively. Since these materials have a residual effect and are not applied annually, these costs should be spread over a number of years. It is usually assumed that, under West Virginia conditions, limestone applications in pasture will be effective over a ten-year period, and that the effect of superphosphate will last for at least five years. On the basis of these assumptions the annual cost of lime and superphosphate would be $0.98 and $1.25 for 1940 and 1941 pastures, respectively. These costs do not include the cost of applying the materials or interest charges.

The cost of application will vary with the nature of the pasture. However, it would appear that, on the average pasture the cost of apply-

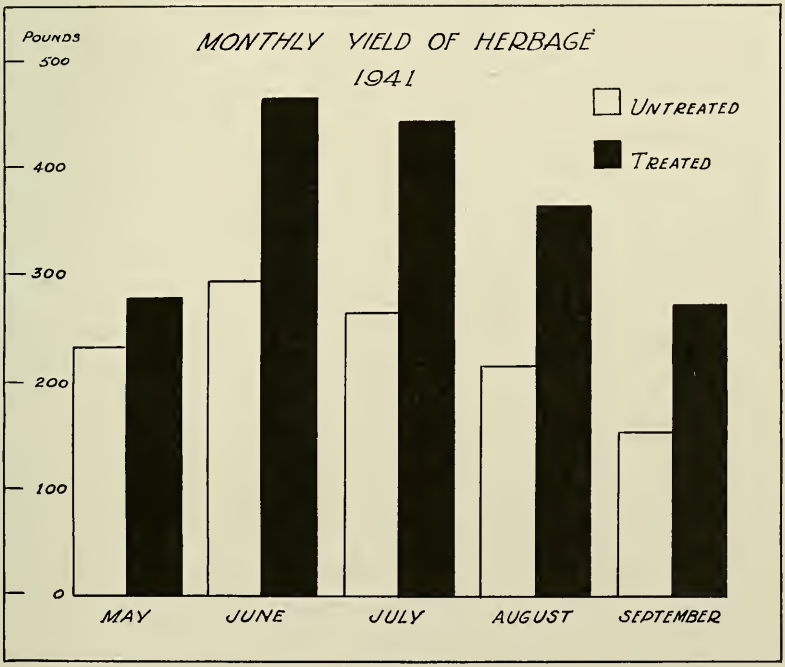

FIGURE 2

ing lime and superphosphate may be about 20 cents per acre per year. Interest charges at 5 percent would add 20 and 25 cents per acre for 1940 and 1941. The total annual cost of treatment would be therefore $1.38 and $1.70 per acre per year for pastures studied in 1940 and 1941 respectively.

Greater difficulty is experienced in attempting to evaluate the returns from pasture treatment. Yield data are valuable but one can only approximate the actual cash value of a pound of pasture herbage, particularly when it is of such variable composition as the ones tested.

According to Johnstone-Wallace* a cow may eat 150 pounds of green grass containing 30 pounds of dry matter per day. On this basis the increases in yield of dry matter for areas having adequate treatment in 1940 amount to 438 pounds per acre, sufficient for 14.6 additional days per acre. The same calculations applied to all 1941 values give 654 pounds additional dry grass or 21.8 days additional pasture per acre. While these values do not appear to show a great increase, it must be remembered that the untreated pastures, by the same calculations, yielded only 18.4 days pasture in 1940 and 38.2 days in 1941. However, when one considers the length of pasture seasons measured (91 days in 1940 and 160 days in 1941), the carrying capacities of the untreated pastures were 4.95 and 4.19 acres per animal unit respectively for the two years. Treatment increased the carrying capacities to 2.76 and 2.67 acres per animal unit for 1940 and 1941 respectively. These values for carrying capacity are reasonably close to the values estimated by farmers.

The above data give only increases in carrying capacity which must be converted into cash returns in order to arrive at the return from pasture improvement. Pasture value may be calculated from the price paid as rental for pasture. This is usually figured on the basis of one animal unit. During the period under study the prices paid were usually from $2.00 to $2.50 per month. If an average figure of 7 cents per day is used and the pasture season is figured as 7 months or 210 days, the rental value of the untreated pastures would be $2.97 and $3.51 per acre for the 1940 and 1941 areas, respectively. The value of increase in these cases would be $2.36 and $2.00 as compared to a cost of treatment of $1.38 and $1.70. Thus the pastures considered as having adequate treatment in 1940 show a profit of 98 cents per acre, whereas the average of all pastures in 1941 shows a profit of 40 cents per acre.

It is apparent that the foregoing discussion and calculation has been based entirely on the increase in production obtained through pasture treatment. Data presented earlier, however, showed conclusively that there was a very marked difference in the *quality* of the forage produced on treated and untreated areas. The increase in desirable grasses and legumes on the treated areas would undoubtedly furnish more digestible nutrients per pound which would result in greater gains in weight, better quality, or higher milk production. This would therefore increase the cash value of the treated pastures beyond that reported above.

There are also other considerations which make the complete evalua-

* Johnstone-Wallace, D. B. Pasture Improvement and Management. Cornell Extension Bulletin 393. 1938.

tion of pasture treatment difficult. The data have shown that much better coverage was obtained on the treated areas. This is an important factor in preventing and controlling erosion and is important both from the viewpoint of maintaining soil fertility and of guaranteeing the future. How to convert this service resulting from treatment into a cash appraisal presents many problems since soil types vary greatly, not only in their productive capacity but also in their erosive qualities.

Another question faced in an economic evaluation of the results of pasture treatment is: How much of the cost of treatment might logically be charged off to increased capitalization? If the productive capacity of the land is increased, the quality of the forage improved, the problem of erosion reduced, then the land, for pasture purposes, has appreciated in value. Is it not reasonable, therefore, to recognize that some part of the cost of treatment is capitalized over a period of time in maintained or increased land values?

Although it is possible to express results of pasture treatment either in terms of total yield, of total digestible nutrients, or of pounds gain in the case of feeding trials, this gives only a part of the story from an economic viewpoint. With so many variables involved, there is yet to be worked out a satisfactory conversion factor which will truly express all of the benefits or values of pasture treatment in terms of money evaluation.

It was pointed out that the tests in this experiment were on a farm basis and not on a plot basis. There were many factors which could not be accurately controlled such as soil type, slope, exposure, rate of application, exact boundaries of treatment, etc. The chief value of this study lies in showing, not what results might be obtained experimentally on uniform plots but what results actually were obtained on farms under operating conditions. Farmers were convinced of the value of pasture improvement.

The tests made showed conclusively that very favorable results can be obtained even on very ordinary pastures. It was and is recommended that the better pastures be treated first. The response per unit of application is always greater and consequently more profitable. How poor a pasture one can afford to treat is a very pertinent question. The response to treatment on some of the poorer pastures under test was beyond any expectation. No definite answer to this question has as yet been reached.

SUMMARY AND CONCLUSIONS

A study of the effect of liming and fertilizing on 44 Upshur County pastures was made during 1940 and 1941. The yields were measured by clipping caged areas with a lawn mower and weighing the dried clippings.

The lime and fertilizer had been applied by farmers cooperating in the Agricultural Conservation Program from one to three years before the test. Burnt lime was used on 27 areas, ground limestone on 15 areas, and marl on two areas. The average rates of application were 1396 pounds per acre for burnt lime, 2067 pounds per acre for ground

limestone, and 1500 pounds per acre for marl. Soil analyses indicated that the amounts used were insufficient in many cases to raise the soil reaction to the optimum pH for bluegrass and white clover.

Most of the farmers used either 20 percent or 45 percent superphosphate. The eleven farmers using 20 percent superphosphate applied an average of 306 pounds per acre. Thirty-two farmers used 45 percent superphosphate at an average rate of 163 pounds per acre. One farmer used 16 percent superphosphate at the rate of 200 pounds per acre. The applications generally increased the content of available phosphorus in the soil but the amount of increase was not sufficient for optimum growth of bluegrass and white clover in many areas.

Most of the farmers observed increases in carrying capacity as a result of treatment, the average increase being 86 percent in 1940 and 91 percent in 1942. All farmers indicated that they thought money spent in pasture improvement was a profitable investment.

As a result of soil tests certain of the areas were designated as having "inadequate treatment." Possible explanations for failure of treatment to show in the soil analysis are given. These areas gave smaller changes in yield and quality of vegetation than those areas in which soil tests showed marked differences in pH and available phosphorus. In 1940 the areas designated as having "inadequate treatment" showed an increase in yield of 15 percent as a result of treatment as compared to 79 percent increase for the areas having adequate treatment. The average increase in yield in 1941 as a result of treatment was 57 percent for all plots and 68 percent for the areas receiving adequate treatment. These increases in yield were well distributed throughout the pasture season.

Estimates of cover showed that the treated plots had more legumes and desirable grasses, particularly more white clover and bluegrass, and less bare ground than the untreated areas. The increase in legumes was also evident in the sorted samples and caused an increase in the protein content of the clipped herbage.

Calculations of the estimated pasture value of the increased yield as compared to costs showed that, on the average, the treatments had been profitable. The net gain per acre for areas receiving adequate treatment was 98 cents on the areas studied in 1940 and 50 cents on the areas studied in 1941. These values do not include such factors as (1) improved quality of the herbage, (2) increased control of erosion, and (3) increased value of the land, all of which would add to the cash value of pasture improvement and result in a still greater profit.

The studies indicate the importance of applying sufficient lime to make the soil reaction favorable for bluegrass and clover and of applying sufficient superphosphate to furnish a plentiful supply of phosphorus for the desirable pasture species. Where both of these conditions are met it would appear that a large percentage of the pastures in the state will give profitable returns for the lime and phosphate added. The greatest returns will usually result from treatment of the better pastures because smaller amounts of lime and superphosphate will usually be needed and the increased herbage will have a higher nutritive value.