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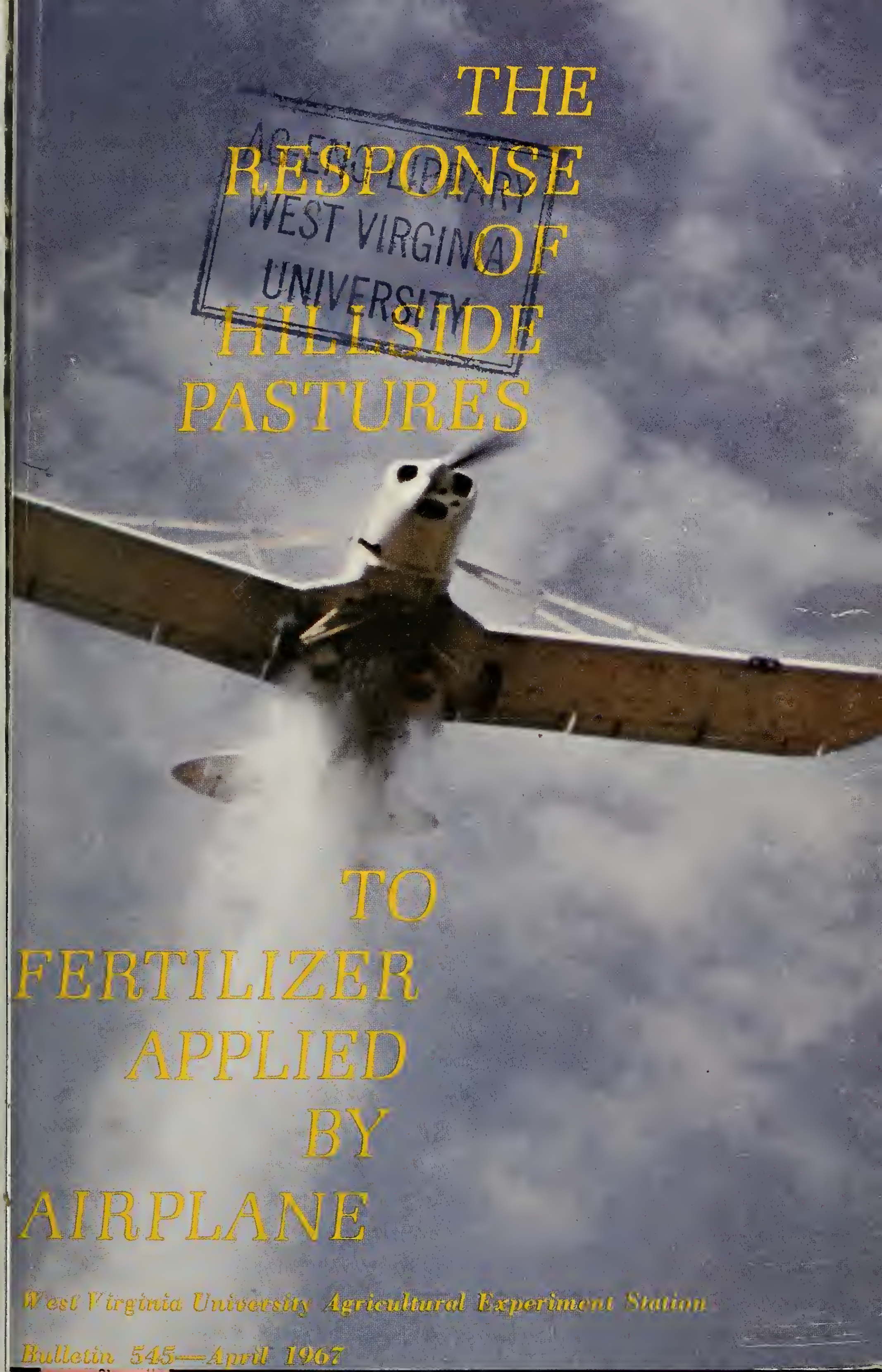

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The Response of Hillside Pastures To Fertilizer Applied By Airplane

G. A. JUNG, J. A. BALASKO, and G. E. TOBEN

INTRODUCTION

THE IMPORTANCE of pasture production in West Virginia is revealed in the 1964 census. Dairy, beef, and sheep enterprises accounted for 49 per cent of the value of farm products sold in West Virginia in 1964. The total land pastured in the State in that year was 2,875,249 acres, 54 per cent of the total land in farms. Excluding woodland pasture, there were 1,965,155 acres of other pasture, only 16 per cent of which was classified as improved.

Most of the parent materials from which West Virginia soils were derived are relatively low in base and phosphorous content. During the soil development processes, the base content was depleted by leaching. Cropping following the removal of the forests further depleted plant nutrients. The land generally was utilized for pasture when erosion became a problem or when crop production became too low to be profitable. Even though West Virginia has been blessed with a climate ideally suited for the growth of many pasture grasses and legumes, agronomic studies over a 30-year period clearly show that very little of this forage potential can be obtained without fertilization. Indeed, the major limiting factor in livestock farming in all of Appalachia today is fertilization.

Experiments conducted in West Virginia and elsewhere in the northeastern region of the United States have shown that pastures of desirable botanical composition can be attained through adequate liming, fertilization, and management. These pastures have a higher carrying capacity, more nearly satisfy the dietary needs of livestock, and therefore result in an improved quantity and quality of products produced. The fertilized pastures are more resistant to erosion losses and provide the best land-use for that portion of the farm which is not suitable for more intensive cropping. Pasture improvement through liming and fertilization is a "must" if profitable returns are to be realized, particularly on small farms, and if erosion losses are to be kept to a minimum.

Topography has been one reason for the limited fertilization of permanent pastures, but with aerial fertilization even topography is of a small consequence. This report summarizes the results of experiments designed to measure and evaluate the response of hill pastures, varying in soil type and soil pH, to fertilizer applied from an airplane.

LITERATURE REVIEW

Permanent pastures have been reported to respond favorably in yield to the application of lime, nitrogen, phosphorus, and potassium separately and in all combinations. Under West Virginia conditions, it has been shown by Odland *et al.* (18) and Robinson and Pierre (24) that applications of lime increased pasture yields. In later studies Schaller and Pohlman (27) found that phosphate efficiency was improved by lime. Pohlman and Cornell (21) evaluated the residual effects of lime and phosphorus applications on 44 pastures in Upshur County after one, two, or three years following treatment. On the average, the pastures had been treated with 1,396 pounds per acre of burnt lime, 2,067 pounds per acre of ground limestone, or 1,500 pounds per acre of marl and approximately 30 pounds per acre of phosphorus. Of the pastures receiving "adequate" treatment, 65 per cent of the treated plots had dry-matter yields greater than 50 per cent above those for the respective untreated plots. The authors noted that in many instances the treatments did not raise soil pH or available phosphorus content to levels considered optimum for the growth of bluegrass or white clover. Furthermore, treatment resulted in dry-matter yields 50 per cent above the yields from untreated pastures when many of the treated pastures had a soil pH less than 6.0 and the soil available prosphorus content was less than 40 pounds per acre.

Studies involving nitrogen fertilization of pastures have indicated significantly higher yields with nitrogen applications (4, 7, 8, 16, 25, 30). The increased yields attributed to a given level of nitrogen fertilizer can be affected by botanical composition (8, 16), time of application (4, 25), and climatic conditions (8, 16, 25).

Several investigators have concluded from fertility studies with permanent pastures that phosphorus is the most limiting nutrient, and this is especially true where legumes are present (7, 16, 24). Schaller and Pohlman (27) reported that the frequency of phosphate application was of far less importance than the total amount applied.

From many pasture experiments in Northeastern United States, workers have concluded that potassium is not the most limiting nutrient, and only after phosphorus has been supplied does potassium appear limiting. Brown *et al.* (4) pointed out that grazing animals return a considerable amount of potassium to the soil. Bear and Salter (1) reported that while 90 per cent of the West Virginia soils need lime, most of the soils are fairly well supplied with potassium. Bryan and Deatrick (6) working with 485 soil samples, including the agriculturally important soil series in West Virginia, found that all of the soils sampled averaged 1 per cent potassium or more. However, they did not determine how much of the potassium was available for plant growth. Robinson and Pierre (24) concluded that some West Virginia pastures would respond profitably to potassium fertilization, but that, in general, applications of lime and phosphorus would be most profitable.

Pierre *et al.* (19) concluded that the type of vegetation and low-carrying capacity of most permanent pastures in West Virginia were due to soil acidity and depleted soil fertility. Soils with a pH of 5.8 or above supported good growth of Kentucky bluegrass and white clover, provided other factors were favorable. Odland *et al.* (18) reported considerable improvement in the quality of pastures which had received lime. Under certain conditions it has been found that nitrogen fertilization favors the growth of grasses at the expense of clover (4, 7, 8, 24, 26, 29), whereas clover replaced undesirable grasses and weeds in pastures treated with lime and/or superphosphate (4, 7, 17, 21, 28). Odland *et al.* (18) and Brown *et al.* (4) found that lime and superphosphate were responsible for a greater increase in desirable species than superphosphate alone. Midgley and Weiser (14) pointed out that white clover is an important component of permanent pastures because it provides nitrogen for the grasses early in the spring, a more uniform distribution of seasonal yield, and reduces soil temperature. The importance of the latter was shown in another experiment in which soil temperatures above 60° F. were found to inhibit rhizome and root growth of bluegrass (5).

In a description of the results of an experiment designed to compare the nutritive value of various forages, Swift *et al.* (31) expounded upon the interpretation of such experiments.

> In attempting to compare the relative feeding value of various forages as reported in the literature, the investigator becomes keenly aware of the prevailing inequality of important factors influencing results. These factors, seldom if ever the same in any two cases, include weather, soil fertility, stage of maturity of the grass when cut, and conditions of drying for the production of hay.

Investigators have measured the content or digestibility of several plant constituents to evaluate the nutritive value of pastures. The quantities of protein obtained in pasture experiments were related to the amount of clover or nitrogen fertilization (2, 9, 10, 11, 15, 22, 23, 25, 28, 32). Brown and Munsell (3), Schaller *et al.* (28), and Vinall and Wilkins (32) found that when legumes were abundant, protein content of the forage was not increased with nitrogen fertilization. Several investigators (2, 13, 15, 20, 32) reported increased amounts of phosphorus in herbage from pastures receiving phosphate fertilizer. Schaller *et al.* (28) have shown that pastures which were adjusted to a pH of 6.5 and treated with 500 pounds of 20 per cent superphosphate and 100 pounds of muriate of potash produced herbage with a higher content of calcium, phosphorus, and potassium than untreated pastures seven years after fertilizer application. Reid *et al.* (23), working with bluegrass, reported significant increases in protein content and digestibility of cellulose, protein, and dry matter as nitrogen applied to pasture increased from 60 pounds per acre to 240 pounds per acre. The increases were observed in the first growth but were not evident in aftermath growth. Over a 30-year period, Brown *et al.* (4) found that 80 pounds of phosphate per acre every three to five years increased the total digestible nutrients by 60 per cent over the unfertilized check which averaged 500 pounds of digestible nutrients per acre per year. Lime in addition to superphosphate accounted for a 109 per cent increase in the total digestible nutrients over the unfertilized check. Eheart and Pratt (9) found that with an annual application of 100 pounds of triple superphosphate and 50 pounds of nitrogen, protein digestibility increased while no change was observed in the digestibility of dry matter, crude fiber, ether extract, and nitrogen free-extract.

EXPERIMENTAL PROCEDURE

In the spring of 1963, areas of 20-30 per cent slope within nine permanent pastures located in Monongalia County were chosen to determine the effects of aerial fertilizer applications on hillside pasture. Within these areas three representative soil series of the county and three pH levels were present. The three pH levels were present within each soil series. The soil characteristics of the areas are presented in Table 1.

Six plots, each 4 feet square, were chosen within each of the areas and three were randomly assigned as control and three as treated. Plots designated as treated were fertilized from a fixed wing aircraft spreader adjusted to deliver 300 pounds of 14-56-0 per acre. The amount of fertilizer being applied was determined by placing two five-gallon buckets at each site. The fertilizer was produced by the Tennessee Valley Authority and was applied as a composite mixture of 0-60-0 and 21-54-0 in a ratio of 1 to 2 respectively. Control plots were covered shortly before the fertilizer was spread with 8 x 12-foot plastic sheets. The majority of the excess plastic was placed on the upper side of the slope above the control plots to minimize the possibility of nutrients being washed into the control plots. The plastic and fertilizer thereon were removed immediately after fertilization and wire cages 4 x 4 x 2 feet were placed over all plots.

Plots were cut 1½ inches above the soil surface with a mower when the treated plots had accumulated 4 inches of growth. Climatic conditions permitted three cuttings during 1963 and five during 1964. Crude protein and digestible dry-matter determinations were made on forage produced during 1963 according to procedures described by Jung *et al.* (12).

TABLE 1

Soil Series, pH and Phosphorus and Potassium Content of Pastures Selected for Aerial Fertilization Study

Farm	Soil Series	pH*	Available P* lbs./acre	Available K* lbs./acre
Dalton	Gilpin	4.6 to 4.7 (low)	18	168
Anderson	Gilpin	5.1 to 5.2 (medium)	18	140
Hunter	Gilpin	6.4 to 7.0 (high)	47	129
Thomas	Gilpin-Upshur	4.7 to 5.0 (low)	8	154
Thomas	Gilpin-Upshur	5.2 to 5.5 (medium)	52	161
Statler	Gilpin-Upshur	6.1 to 6.5 (high)	34	128
Garlow	Westmoreland	4.2 to 4.5 (low)	23	182
Kelly	Westmoreland	4.9 to 5.5 (medium)	31	235
Straight	Westmoreland	5.7 to 6.0 (high)	33	207

*Soil pH ranges were determined with a Hellige-Truog Test and then were verified by having at least four samples from each site analyzed by the West Virginia University Soil Testing Laboratory. Available P and K figures represent the average amount of these elements in soil samples taken from the upper three inches of soil.

In order to assess the effect of the fertilizer application under more precise conditions, four plugs 3 inches in diameter and 4 inches deep were taken from each control area (12 plugs from each pasture). The plugs were chosen as uniformly as possible with respect to desirable species and plant density. The plugs were put in styrofoam containers and randomly placed under artificial light. Six of the 12 plugs from the untreated area of each pasture were randomly assigned as control and six as treated. Plugs designated as treated received the equivalent of 300 pounds of 14-56-0 fertilizer per acre in liquid form. The fertilizer was of the same type as that applied to the field plots. Temperature and moisture were approximately optimum for growth.

RESULTS AND DISCUSSION

The low amounts (less than 50 pounds per acre) of phosphorus available for plant growth at the initiation of this study (Table 1) are typical of phosphate levels found in most pastures in West Virginia. One objective, therefore, of the aerial fertilization program was to increase the amount of phosphorus available for plant growth. It was assumed that high levels (more than 90 pounds per acre) of phosphorus would encourage clover growth, which, in turn, would provide nitrogen for grasses. Potassium levels were not considered as limiting to plant growth in these pastures.

Dry-matter yields (weeds not included) harvested from fertilized and unfertilized pastures representing three soil series, each with three pH levels, are presented in Table 2. Increased yields of forage with fertilization were observed for each cutting (data not presented) throughout the 1963 season. An average increase of 103 per cent in dry-matter yield was obtained for fertilized plots over unfertilized plots even though there was a moisture deficiency (6.3 inches less than normal) during the 1963 growing season (Table 3). Significant increases in yield between the treated and control plots were observed on six of the nine pastures. Significant increases did not occur on the medium pH Gilpin soil, the low pH Gilpin-Upshur soil, and the low pH Westmoreland soil; however, increases of 65, 117, and 34 per cent, respectively, were observed. Variation in plant density, kinds of species, and rate of fertilizer application from plot to plot resulted in low precision; hence, large differences in amounts of dry matter per acre were needed for significance. On the average, all three soil series responded to fertilization, but no significant differences in yield were noted among soil series. Significant increases in yield were obtained for fertilization at all soil pH levels. The average yield was significantly higher with the fertilized high pH soil than with the fertilized low or medium pH soils, whereas no differences were noted among yields for control plots.

TABLE 2

Yields of Weed-Free Dry Matter from Fertilized and Unfertilized Pastures Representing Three Soil Series and Three pH Levels

Soil	pH	Dry-Matter Yields (Tons per acre)			
		1963		1964	
		Fertilized	Control	Fertilized	Control
Gilpin	Low	.81 bc*	.43 def	.63 efg	.33 fg
Gilpin	Medium	.66 bcd	.40 def	.78 def	.85 de
Gilpin	High	.70 bcd	.34 ef	1.21 abcd	.73 defg
Gilpin-Upshur	Low	.65 bcde	.30 ef	1.00 bcde	.65 efg
Gilpin-Upshur	Medium	.56 cde	.19 f	.75 def	.59 efg
Gilpin-Upshur	High	1.26 a	.66 bcd	1.47 ab	.86 de
Westmoreland	Low	.47 def	.35 def	.29 fg	.22 g
Westmoreland	Medium	.96 ab	.32 ef	1.44 abc	.71 defg
Westmoreland	High	.86 bc	.39 def	1.66 a	.95 cde
Averages:					
Gilpin		.72 a	.39 b	.87 ab	.64 b
Gilpin-Upshur		.82 a	.38 b	1.07 a	.69 b
Westmoreland		.77 a	.35 b	1.13 a	.63 b
	Low	.64 b	.36 c	.64 cd	.40 d
	Medium	.73 b	.30 c	.98 b	.71 bc
	High	.94 a	.46 c	1.45 a	.85 bc
All Pastures		.77 a	.38 b	1.03 a	.65 b

*Data followed by a common letter are not significantly different. Comparisons may be made within each year, with averages considered separately.

On the average, 1964 dry-matter yields were higher than those of 1963. This was a result of a more favorable season with respect to rainfall (Table 3) and an earlier first cutting date. The percentage increase in yield due to treatment, however, was higher (103 vs. 58) in 1963 than in 1964 (Table 2). Lack of nitrogen probably was the reason for the smaller response, because there was not an abundance of clover in most plots during 1964 and little or no carry-over of nitrogen from the previous year. This hypothesis was tested by studying the relationship between dry-matter yield and percentage of clover in each treated and untreated

TABLE 3

Monthly Air Temperatures, Total Precipitation, and Departures from Normals During The 1963 and 1964 Growing Seasons*

Month	Year	Air Temperatures °F. and Departures from Normal						Total Precipitation Inches and Departures from Normal	
		Avg. Max.	Dep.	Avg. Min.	Dep.	Avg.	Dep.	Inches	Dep.
March	1963	56.2	5.7	35.3	4.2	45.8	4.9	6.55	3.15
	1964	52.0	1.5	31.6	0.5	41.8	0.9	3.91	0.51
April	1963	64.3	1.0	40.0	1.2	52.2	–0.1	1.45	–1.88
	1964	64.7	1.4	43.3	2.1	54.0	1.7	4.66	1.33
May	1963	72.7	0.0	47.9	–2.2	60.3	–1.1	1.36	–2.27
	1964	74.4	1.7	51.2	1.1	62.8	1.4	1.25	–2.38
June	1963	80.1	–0.5	57.6	–0.8	68.9	–0.6	5.35	1.13
	1964	79.9	–0.7	57.9	–0.5	68.9	–0.6	4.62	0.40
July	1963	83.4	–0.2	60.1	–2.2	71.8	–1.2	1.39	–2.66
	1964	82.3	–1.3	62.7	0.4	72.5	–0.5	3.91	–0.14
August	1963	78.6	–3.8	58.3	–2.8	68.5	–3.3	3.41	–0.70
	1964	79.2	–3.2	57.8	–3.3	68.5	–3.3	4.77	0.66
September	1963	73.7	–2.8	49.9	–4.3	61.8	–3.6	1.90	–0.93
	1964	76.7	0.2	51.8	–2.4	64.3	–1.1	3.44	0.61
October	1963	73.3	6.4	44.2	–0.7	58.8	2.9	0.24	–2.18
	1964	------	------	------	------	------	------	-----	------

*All departures from normals are based on the period 1946-1963.

pasture. The relationship was found to be highly significant (1 per cent level). In both seasons the greatest percentage increase in dry-matter yields occurred at midseason and the least percentage increase in the latter part of the season (data not presented). Lower total dry-matter yields were harvested in 1964 than in 1963 from the low pH Gilpin soil and the low pH Westmoreland soil. Both of these pastures were undergrazed at the beginning of the experiment; therefore, large amounts of excess growth were included in the first cutting of 1963. This was not the case in 1964 and the corresponding growth response from the fertilizer and more desirable climatic conditions were not large enough to equal that of the excess growth, thus lower yields resulted. In 1964 only the yields from the treated plots on the high pH Gilpin-Upshur soil and the medium and high pH Westmoreland soil were significantly larger than those from the control plots. Again in this year due to large variance among pastures, other increases of large proportions were not significantly different. Average yields for fertilized and control plots representing the three soil series indicated that the fertilizer effect was significant for the Gilpin-Upshur and Westmoreland soils and that yield was not affected by soil series. With regard to pH levels, only the high pH soils responded significantly to fertilization. Increased yields were noted with increasing soil pH levels of the fertilized plots and between the low pH soils and the medium or high pH soils of the control plots.

If yields for the two-year period are considered, the response to fertilization resulted in yield equivalents from .21 to 1.56 tons of hay* per acre. On the average, the Gilpin soil was least responsive (.64 tons of hay per acre), the Gilpin-Upshur soil was intermediate in response (.92 tons of hay per acre), and the Westmoreland soil was most responsive (1.04 tons of hay per acre) to fertilization. Increased yields were noted with an increase in soil pH. At the low soil pH the equivalent of .59 tons of hay per acre were produced, whereas the respective yields for the medium soil pH and high soil pH were .79 and 1.23 tons of hay per acre. While these trends did exist, it should be pointed out that yields from two pastures (medium pH Gilpin soil and low pH Westmoreland soil) lowered the averages considerably. An explanation for the small responses for these two pastures is offered later in the discussion.

The importance of botanical composition in each pasture was illustrated vividly in this study. In both years the largest increase in yield due to fertilization occurred on the medium pH Westmoreland soil. This pasture rated as one of the best with respect to desirable species (Table 4). On the other hand, the low pH Westmoreland soil gave the least response to fertilization in 1963. Of the nine pastures, this pasture had the highest percentage of weeds and the least amount of clover (Table

* (dry matter X 1.137)

4). Further investigation of this pasture showed that some Guernsey soil was present as well as Westmoreland soil. The Guernsey soil, because of its structure, probably limited clover establishment. The least response in 1964 to the fertilizer (applied in 1963) was noted for the medium pH Gilpin soil. In both years, the control plots in this pasture had a higher percentage of clover than the treated plots; and therefore, the effects of the clover may have tended to equalize the effects of the fertilizer. These pastures provide good examples of the close association between botanical composition and productivity.

Forage of more desirable botanical composition was harvested from the treated plots than from the control plots (Table 4). Bluegrass, orchardgrass, and clover made up most of the desirable species; and on the average, treated plots contained higher percentages of these species and lower percentages of other grasses and weeds than the control plots. Desirable species, harvested from treated plots when compared with those harvested from control plots, made up 15 per cent more of the total forage harvested in 1963 and 20 per cent more in 1964 (data not presented). When all plots are considered for both years, bluegrass, orchardgrass, and clover represented 47 per cent of the total forage produced on the Gilpin soil. These same species represented 54 per cent of the forage produced on the Gilpin-Upshur soil and 55 per cent of that produced on the Westmoreland soil. The plots on the high pH Gilpin soil, medium and high pH Gilpin-Upshur soil, and high pH Westmoreland soil were the only ones where appreciable amounts of orchardgrass were present. Bluegrass, orchardgrass, and clover made up 40 per cent of the forage harvested from the pastures with a low soil pH, 52 per cent of the forage from pastures with a medium soil pH and 59 per cent of the forage from pastures with a high soil pH.

Amounts of digestible dry matter and crude protein harvested in 1963 from the nine pastures are given in Table 5. Treated pastures on the average produced 520 pounds more digestible dry matter per acre than did the control pastures from which 451 pounds of digestible dry matter per acre were harvested. Treated pastures produced 230 pounds of crude protein per acre as compared with 93 pounds from the control pastures. Both of these evaluations show that greater benefits were derived from fertilization than was indicated by dry-matter yields. Furthermore, observations in the field indicated that animal preference was greater for the fertilized forage than for the unfertilized forage. In fact, on the high pH Westmoreland pasture, animals did not consume untreated forage until the fertilized area was completely grazed.

As a result of fertilization, the production of digestible dry matter and crude protein was increased by more than 100 per cent on all pastures except those on the medium pH Gilpin soil and the low pH Westmore-

TABLE 4

Botanical Composition of Forage Harvested from Nine Pastures, Representing Three Soil Series and Three Soil pH Levels During 1963-64*

Soil	pH	Bluegrass		Orchardgrass		Other Grasses		Clover		Weeds	
		Fert.**	Cont.**	Fert.	Cont.	Fert.	Cont.	Fert.	Cont.	Fert.	Cont.
Gilpin	Low	36	16	0	0	30	51	17	3	17	29
Gilpin	Medium	32	22	0	0	31	32	17	30	21	16
Gilpin	High	24	18	10	1	20	39	24	16	22	25
Gilpin-Upshur	Low	15	9	0	0	45	55	21	14	19	21
Gilpin-Upshur	Medium	28	13	4	20	27	25	19	19	21	24
Gilpin-Upshur	High	28	25	19	16	13	21	29	16	12	22
Westmoreland	Low	54	48	2	0	8	11	3	0	33	39
Westmoreland	Medium	28	17	1	2	23	50	35	15	13	16
Westmoreland	High	14	11	34	22	21	33	20	6	12	28

*Per cent of the total dry matter harvested.
**Abbreviation for fertilized and control.

TABLE 5

Digestible Dry Matter and Crude Protein Harvested in 1963 From Nine Pastures, Representing Three Soil Series and Three pH Levels, Under Two Fertility Levels

Soil	pH	Digestible D.M. (lbs. per Acre)		Crude Protein (lbs. per Acre)	
		Fertilized	Control	Fertilized	Control
Gilpin	Low	980	480	206	86
Gilpin	Medium	820	520	188	104
Gilpin	High	820	360	198	70
Gilpin-Upshur	Low	820	380	198	74
Gilpin-Upshur	Medium	720	260	180	50
Gilpin-Upshur	High	1700	800	374	166
Westmoreland	Low	560	400	126	80
Westmoreland	Medium	1220	400	308	94
Westmoreland	High	1100	460	294	116
Averages:					
Gilpin		873	453	197	87
Gilpin-Upshur		1080	480	251	97
Westmoreland		960	420	243	97
	Low	787	420	177	80
	Medium	920	393	225	83
	High	1207	540	289	117
All Pastures		971	451	230	93

land soil. Of the control plots, those on the medium pH Gilpin soil produced the second largest amount of digestible dry matter. The crude protein data indicate that the plants in the treated plots of this pasture did receive nitrogen, but only a 58 per cent increase in digestible dry matter and an 81 per cent increase in crude protein were observed. These increases were only half as large as those observed for the other locations. Based on these results, it appears that the smaller increases in digestible dry matter and crude protein were related to the higher content of clover in the control plots. Large amounts of growth in the first harvest (because of being undergrazed) from both the treated and control plots on the low pH Westmoreland soil, as well as the lack of legumes in these plots, may account for the small increases in digestible dry matter and crude protein.

Response to fertilization for the Gilpin soil was inferior to that of the Gilpin-Upshur soil and Westmoreland soil in the production of both digestible dry matter and crude protein. The average increase in digestible dry matter and protein production due to fertilization became greater as pH increased. However, the highest soil pH readings were recorded for the high pH Gilpin soil, whereas production from the treated plots on this pasture rated only a tie for fifth place among all the pastures, and the control plots produced the second lowest yields recorded.

The information presented above raises at least three questions: (a) Were environmental conditions (especially soil moisture) more favorable for plant growth at some locations than at others? (b) How accurate were the aerial applications of fertilizer? and (c) Did the difference in white clover content of the pastures result in an unfair comparison among pastures?

Answers to these questions were sought by assessing the effect of fertilizer on productivity under uniform environmental conditions. Fertilizer was applied uniformly to 6 of 12 pots containing plugs which had been removed from the field control areas in each pasture. The growth of these fertilized plants was compared with the growth of unfertilized plants in the other 6 pots under uniform temperature, light, and moisture conditions. An aggressive growth of clover on the treated plugs from the high pH Westmoreland soil resulted in both large yields of forage and the largest yield increase due to fertilization. The growth of clover appeared to be favored over the growth of grass under the conditions of this experiment. Plants from the medium pH Westmoreland soil responded least to the application of fertilizer. This response was unlike that observed in the field and was associated with a relatively poorer performance of the treated plugs and a relatively better performance of the control plugs than was obtained with plants in the field. The difficulty of selecting uniform plugs with a representative botanical composition may, however, account for the variation in this and other responses. Nevertheless, increases in yield ranging from 21 to 193 per cent resulted from fertilization, and the average yield increase was 90 per cent which compares favorably with the response (103) obtained in the field in 1963. Furthermore, total dry weight for four cuttings from the plugs was significantly correlated with the 1963 (5 per cent level) and 1964 (1 per cent level) yields.

Two other methods were used to determine whether fertilizer was applied by the aircraft on the field plots. Examination of the covers placed over control areas indicated that in every instance fertilizer was deposited on the pastures. The other method involved the measurement of fertilizer that fell in buckets placed between the areas designated for the treated and control plots. Fertilizer collected in this manner indicated that an average of 250 pounds per acre was applied. Some variability in fertilizer collected among farms was noted, but this may be explained, at least in part, by the various angles at which the plane was flying in relation to the hillside (and buckets) when the fertilizer was applied. An important finding, however, was that there was little relationship ($r = .32$) between the amount of fertilizer collected and yield response to fertilization in 1963. If the bucket technique was valid for estimation of fertilizer deposition, the low correlation suggests that in addition to fertilizer, other factors affected yield responses.

With regard to the third question, it is pertinent to point out that the amount of clover in the nine pastures varied from zero to 46 per cent of the total dry weight during the two-year period. After the effects of the nitrogen fertilizer disappeared, pasture productivity would depend on phosphorus availability and the abundance of clover. Without a legume to provide nitrogen, only small yield increases could be expected even if phosphorus were available for plant growth. To answer question three, white clover seed was broadcast over the surface of every plug after four harvests were obtained from the plugs and then two more harvests were taken (Table 6). The seeding of clover, therefore, permitted comparisons in which the absence of clover was not considered as limiting the growth of grasses. The addition of clover resulted in higher yields for most of the fertilized and control plugs. The increase, however, was larger for the fertilized plugs than for the controls. Plugs from three pastures, i.e., medium pH Gilpin soil, high pH Gilpin-Upshur soil, and medium pH Westmoreland soil were affected much more than were the other six. The effect of the clover being added was sufficiently great to completely change the productivity ranking of the plugs. Dry-weight yields from the fourth cutting (before clover seeding) were significantly (5 per cent level) correlated with yields of the fifth cutting but were not correlated with yields of the sixth cutting, whereas yields from the fifth and sixth cuttings were highly correlated (1 per cent level). The appearance of the clover was not uniform (Table 7). Fertilizer had virtually no effect on clover appearance, whereas soil type and pH did. On the average, the highest percentage of healthy clover was found on the Gilpin soil and the least on the Gilpin-Upshur soil, whereas the reverse was true for the unthrifty clover plants. More than three times as many plugs containing healthy clover plants were found among the high pH plugs than the low pH plugs and the reverse was true for

TABLE 6

Dry Matter Harvested from Fertilized and Unfertilized Plugs, Representing Three Soil Series and Three pH Levels and Grown Under Uniform Conditions

Soil	pH	Yield (mg. dry matter per plug) Before adding clover seed Fertilized	Before adding clover seed Control	After adding clover seed Fertilized	After adding clover seed Control
Gilpin	Low	479*	190	939**	577
Gilpin	Medium	405	178	1546	959
Gilpin	High	451	235	808	592
Gilpin-Upshur	Low	544	341	590	549
Gilpin-Upshur	Medium	415	308	536	657
Gilpin-Upshur	High	426	215	1530	562
Westmoreland	Low	333	181	946	425
Westmoreland	Medium	423	351	1823	1433
Westmoreland	High	895	305	1404	641
Averages:					
Gilpin		445	201	1098	709
Gilpin-Upshur		462	288	885	589
Westmoreland		550	279	1391	833
	Low	452	237	825	517
	Medium	414	278	1301	1016
	High	591	252	1247	598
All Plugs		486	256	1125	710

*Average weight for four cuttings and 6 replications.
**Average weight for two cuttings and 6 replications.

the distribution of the unthrifty clover plants. This undoubtedly could affect or be associated with nodulation which in turn would affect the nitrogen supply for grasses. More information is needed to better understand factors limiting clover growth because, as demonstrated in these studies, clover is a key factor in pasture productivity. The data also suggest that consideration should be given to the possibility of including clover seed with aerial applications of fertilizer when the clover content of the pastures being fertilized is low.

TABLE 7

Appearance of Clover Plants Growing on Soils Representing Three Soil Series and Three pH Levels

Soil	pH	Appearance of Clover Plants		
		Thrifty	Intermediate	Unthrifty
Gilpin	Low	5*	5	2
Gilpin	Medium	7	5	0
Gilpin	High	8	4	0
Gilpin-Upshur	Low	2	6	4
Gilpin-Upshur	Medium	0	7	5
Gilpin-Upshur	High	6	4	2
Westmoreland	Low	0	6	6
Westmoreland	Medium	7	4	1
Westmoreland	High	9	1	2
Totals:				
Gilpin		20	14	2
Gilpin-Upshur		8	17	11
Westmoreland		16	11	9
	Low	7	17	12
	Medium	14	16	6
	High	23	9	4

*Number includes both fertilized and unfertilized plugs. No effect of fertilizer was noted on clover appearance.

SUMMARY

EXPERIMENTS were designed to measure and evaluate the response of hill pastures, varying in soil series and soil pH, to fertilizer applied from an airplane. Dry-matter yields over a two-year (one dry year) period, resulting from a single application of fertilizer, varied from .19 tons per acre to 1.37 tons per acre. Only two pastures had dry-matter increases of less than .50 tons per acre. The small responses were thought to be associated with a lower clover content of the treated plots than the controls (medium pH Gilpin soil) or to the nature of the soil and

previous management (low pH Westmoreland soil—Guernsey soil). Increases in dry-matter yield were highest for the Westmoreland soil and high pH soils and were lowest for the Gilpin soil and low pH soils. The Westmoreland soil produced 64 per cent more forage on the average than did the Gilpin soil, and the high pH soils produced 108 per cent more forage than did the low pH soils. Botanical composition of the pastures was affected more by soil pH than by soil series. Dry-matter yields were highly correlated with the percentage of clover in the plots during the second year and therefore nitrogen became a limiting factor for the growth of grasses in some pastures. Both field observations and laboratory measurements indicated that forage from the fertilized pastures had a higher nutritive value than did forage from the untreated pastures.

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