ROOT DEVELOPMENT STUDIES ON COTTON

A STUDY OF ROOT development of the cotton plant is being conducted under field conditions at the U. S. Cotton Research Station, Kern County, and the West Side Field Station, Fresno County. Since cotton is normally a deep-rooted crop, direct detailed measurements become difficult or impossible. In these studies radioactive phosphorus (P32) is used as a tracer to determine the rate and pattern of development, both vertically and laterally. The method consists of applying P32 solution to various points in the soil surrounding the plant. The presence of roots within an area of application is indicated by the presence of radioactivity in the aerial portion of the plant as a result of P32 uptake. The topmost leaves are selected for this determination since absorbed phosphorus moves rapidly into the new growth.

At any given stage of growth the amount of radioactivity in the plant is a reflection of the density or absorptive activity of roots growing in the area of application. By comparing the relative differences in radioactivity of plants growing above the various placements, it is possible to determine not only the presence or absence of roots in a given location, but also to estimate the relative abundance and absorptive activity in various parts of the root zone at any given time. Since the roots themselves are not disturbed in this determination, successive measurements can be made on the same plant as the season advances.

As an example of some of the results, roots have been shown to extend downward at an average of an inch or more a day to a depth of 6 feet on both a coarse and a fine textured soil at Shafter and Five Points respectively. Toward the end of the fruit setting period in late August, a nearly uniform development to a depth of 4 feet is indicated, with significant absorptive activity also at 5 and 6 feet. Lateral development is less rapid and is greatly affected by competing roots from plants in adjacent rows. A study of this effect, together with the effect of cultural practices on the development of the root system is being continued.—*D. M. Bassett, Department of Agronomy, University of California, Davis.*

Nitrogen Fertilization of North Coastal Grassland

The primary benefit of nitrogen fertilization to grassland areas of north coastal California was the increase in production of forage during the winter season when grass was short and legumes grew very slowly. According to these tests, not more than 80 pounds N per acre should be applied since near maximum forage yields were produced at this rate and little increase in winter production resulted from additional amounts. However, carryover into the second year was measurable only with applications of the 160-pound maximum used in these tests on two soil types. Protein percentages in the nonleguminous plants increased with increasing N application rates during the vegetative stage, but at maturity, the nitrogen percentages in these plants were less where 40 pounds of N per acre had been applied than on the non-treated check plots. The 160-pound rate increased the protein percentage in mature plants. Total nitrogen uptake of all forage species combined, increased during the winter with increasing rates of N applied. However, uptake on the unfertilized plots during the warm spring months, when the clovers grew rapidly, was about the same as that on plots fertilized with 40 pounds of nitrogen per acre.

M. B. JONES

Test plot at the Sutherlin soil site, Hopland Field Station, shows color and height variations resulting from different rates of nitrogen application.

—YIELD, PER CENT PROTEIN, TOTAL UPTAKE

CALIFORNIA'S EXTENSIVE, non-irrigated, annual grassland areas are characterized by a climate which is wet during the cool period of the year and dry during the summer months. The forage has a high percentage of annual grasses and herbs that germinate with the first fall rains, grow slowly during the cool winter period, and mature in the spring after a short period of rapid growth.

Much of the previous information on the effects of nitrogen on California's annual grassland came from experiments where N was applied at a single rate. The purpose of this study was to determine the effect of N—applied at several rates—on yield, protein percentages, and total N uptake of various species at several growth stages. Additional information was obtained on the carryover of N into the second year after application.

Testing procedure

In October 1956, N as urea was applied to annual grassland at the rate of 0, 40, 80, and 160 lbs N per acre, and P was applied at the rates of 0, 18, 36, and 72 lbs per acre as treble superphosphate in all possible combinations. The 16 treatments were replicated 4 times at each of 2 locations at the University of California's Hopland Field Station, Mendocino County. One experimental area was a Yorkville soil site which sloped south-southeast at an elevation of 900 feet. The other area was a Sutherlin soil site which sloped northwest at about 1400 feet. Just prior to fertilization, the old dry grass was removed by burning, and the experimental areas were fenced to prevent grazing by sheep and deer.

In October 1957 the fertilizer treatments were reapplied to one-half of each 7 by 40-foot plot. The half to be refertilized was selected at random. The other half was left to measure fertilizer carryover into the second year. In October 1958, this half was refertilized, leaving the area fertilized in 1956 and 1957 on which to measure carryover. No fertilizer was applied in the fall of 1959.

In 1957, forage production was measured in January, March, April and May on 1 square foot of each plot, using a different quadrat at each cutting. The 1957 results indicated that satisfactory data could be obtained by cutting only twice; once in late winter and once in late spring. Therefore, in 1958, 1959, and 1960, cuttings were made in February or March and again in May. To lessen the degree of variability among plots, production from 3 quadrats in each plot was measured at both cuttings. In 1957, the percent protein was determined on forage samples that had been separated by hand into component species. In subsequent years determinations were made on selected species.

Temperature and rainfall data were recorded at the headquarters weather station at the Hopland Field Station. These data do not represent exact conditions at the plot sites but indicate approximate conditions and year to year variations. Average seasonal rainfall for the 1951 to 1960 period was 36.82 inches. Rainfall and temperature varied widely from year to year during the four years of the experiment. The 1956–57 growing season was relatively cool and dry in the fall, and warm and wet in the spring, with total rainfall amounting to 29 inches. The first rains sufficient to germinate plants came in late October 1956. The 1957–58 season began with heavy rain in late September and continued relatively warm and wet through April with rainfall totaling 60 inches. The 1958–59 season was relatively warm throughout. The first rains sufficient to germinate annual plants came in late November and the total rainfall for the season was 26 inches. The 1959–60 season began with a 2-inch rain on September 18; then no appreciable rain fell until December 23. During the remainder of the year soil moisture supplies were generally adequate. Total rainfall for the season was 28 inches.

The scope of this article is limited to the effects of nitrogen, since the phosphorus treatments resulted in relatively small increases in production in these experiments. Since the yields in January and March were approximately equal, only the March data are presented.

At the March clipping date, total yield increased with increasing rates of N to a maximum at the 80-lbs-per-acre rate. Filaree (*Erodium botrys*) made the greatest contribution to total yield at all N rates on the Yorkville loam, but on the Sutherlin loam the grass increased more than the filaree with each added increment of N. Thus, on Sutherlin loam filaree was dominant when no N was applied, and grass was dominant at the 160-pound per acre rate. Clover, in contrast to grass and filaree, decreased with increasing rates of N.

At the April harvest on the Sutherlin loam, filaree made the greatest contribution to yield at all levels of N. Both filaree and each of the grasses—soft chess (*Bromus mollis*), ripgut (*B. rigidus*), slender wild oats (*Avena barbata*), and fescue (*Festuca* spp.)—increased with increasing rates of N, while legumes (*Trifolium* spp., *Medicago hispida, Lotus* spp.) decreased with increasing N. Maximum production of total forage was reached at 160 lbs N per acre; however, the yield increase over the 80-lb level was not significant. On the Yorkville soil, filaree also made the greatest contribution to production at all N levels. The yields of soft chess and ripgut increased with increasing rates of N, but production of silver hair grass (*Aira caryophyllea*) and stipa (*Stipa pulchra*) changed little as N rates increased.

Trends at the May harvest were similar to those found in April on both soils, except that filaree contributed relatively less to yield than it did in April. This was due primarily to early maturing and shattering of this species. Clover made a relatively greater contribution to yield in the zero N plots at the May harvest on the Sutherlin soil. The high yield of the "other forbs" category at 0 and 40 lbs N on the Sutherlin soil was due to the contribution of lupine (*Lupinus* spp.).

Total production in March and May during the three years fertilizer was ap-

TABLE 1. YIELD OF ANNUAL GRASSLAND SPECIES DURING THE SEASON OF FERTILIZATION WITH INCREASING RATES OF N

N applied lb./A.	Yield, pounds per acre					
	March clipping			May clipping		
	1957	1958	1959	1957	1958	1959
	YORKVILLE LOAM					
0	630	2,300	1,340	1,790	2,880	2,690
40	950	2,590	1,630	2,410	3,840	2,980
80	1,330	2,880	1,920	4,600	4,030	3,550
160	1,330	2,980	1,920	4,260	4,510	4,130
LSD (.05)	280	NS	360	1,210	*	310
	SUTHERLIN LOAM					
0	810	2,500	1,730	3,150	3,840	2,980
40	1,240	3,170	2,500	3,600	5,860	5,090
80	1,650	3,940	2,790	4,910	11,240	6,530
160	1,680	4,710	3,170	5,990	17,090	7,780
LSD (.05)	420	510	340	905	*	815

* Only one replication clipped in May 1958. Therefore, each yield is an average of 4 P levels. At the other clipping dates each yield is an average of 4 P levels and 4 replications.

TABLE 2. CARRYOVER OF N INTO THE SECOND SEASON AS MEASURED BY FORAGE YIELDS OF ANNUAL GRASSLAND SPECIES

N applied lb./A.	Yield, pounds per acre					
	March clipping			May clipping		
	1°58	1959	1960	1958	1959	1960
	YORKVILLE LOAM					
0	2,020	1,440	2,030	3,270	2,500	4,180
40	2,310	1,440	2,020	3,070	2,590	4,080
80	2,210	1,540	2,310	3,361	2,980	4,760
160	2,690	1,730	2,420	3,650	3,260	4,850
LSD (.05)	425	210	NS	*	505	NS
	SUTHERLIN LOAM					
0	2,690	1,730	1,970	3,650	2,880	3,830
40	2,500	1,920	1,940	4,030	3,070	4,440
80	2,400	1,730	2,240	4,990	3,270	5,690
160	3,170	2,017	2,228	9,030	4,230	6,160
LSD (.05)	290	155	NS	*	455	140

* Only 1 replication clipped in May 1958. Therefore, each yield is an average of 4 P levels. At the other clipping dates each yield is an average of 4 levels and 4 replications.

plied is summarized in table 1. In general, these results indicate that maximum, or at least near-maximum, growth up to the March clipping was produced by 80 lbs N per acre. In the May harvest, there was generally some increase in production above the 80-lb level. However, this increase was not nearly as great per pound of N as where the level of N was 80 lbs per acre or less—except in May 1958 when the Sutherlin loam plots, fertilized with 160 lbs N per acre, produced about 17,000 lbs of forage per acre. This resulted from almost ideal growing conditions on the Sutherlin site during the 1957–58 season, enabling the plants to utilize larger quantities of N. No such response to 160 lbs N per acre was noted on the Yorkville site in 1958—possibly because the Yorkville site faced more southerly, had a steeper slope and was more gravelly and shallow than the Sutherlin soil.

Carryover year

The effect of increasing rates of N on forage production the second year after fertilization is given in table 2. Generally carryover into the second year was measurable only with application of 160 lbs N per acre. There were differences in carryover responses at the different locations and at different dates of harvest. On the Sutherlin soil, the carryover into the second year from 160 lbs N per acre increased yields 18% in March 1958, 17% in March 1959, and 13% in March 1960. In May, the same treatment increased yields 147% in 1958, 47% in 1959 and 61% in 1960. Possibly much of the N carried over was tied up in organic form and became available more rapidly during the spring when temperature and moisture conditions were favorable for nitrification. On the more shallow and drier Yorkville site, the marked increase in response to carryover N in May compared to March did not occur.

All rates of N increased the protein percentage in the plants early in the season. As the plants matured, N applied at the lower rates was utilized in additional growth to the extent that the protein in the nonleguminous species was usually decreased with the addition of 40 lbs N per acre. Plants fertilized with 80 pounds N per acre generally had percentages of protein equivalent to that of unfertilized plants; 160 lbs N per acre generally increased the percent protein of the nonleguminous plants.

The effect of the applied N was reflected in the increased uptake of nitrogen by the grasses and filaree and decreased N uptake by clover with each additional increment of nitrogen applied. The clovers made their largest gains in total N from March to April where no nitrogen was applied. Each increment of N applied reduced the legume contribution of N to the forage.

Tall grass of nitrogen-fertilized plots contrasts sharply with untreated check at this rangelend test site, Hopland Field Station, Mendocino County.

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