Influence of Width of Fertilized Band of Soil on Response of Burley Tobacco To Nitrogen and Phosphorus[1]

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The objective of a sound fertilizer placement program is to apply the nutrients in a position that will permit their most efficient utilization by the plant but which will not cause root injury from excessive salts. Broadcasting and band placement are the methods used to accomplish this goal.

The relative crop response to band and broadcast placements of fertilizers has been extensively investigated with most of the principle crops and major elements. In general, band placement has resulted in higher yields than broadcast placement (5, 10, 11). When equal rates were compared, early growth and P absorption by plants were favored more by band placement of P than by broadcasting (4, 9, 12). Band placement combined with sidedressing resulted in higher yields of Maryland tobacco than broadcasting all of the fertilizer (8).

Prummel (10) found no difference in maximum crop yields between band and broadcast applications of fertilizers. However, the quantity of nutrients required to reach maximum yield was less with band placement than with broadcast application. The apparent superiority of band placement was greatest with P, least with N, and intermediate with K. Barber (1) raised the available P to various levels in soils by broadcasting, and then imposed different rates of P in row applications. With low rates of P, corn yields were increased more with row than with broadcast applications. However, the maximum yield obtained by broadcast was greater than with row applications. In similar studies Barber (2) found that with equal amounts of K, row and broadcast applications were equally effective in increasing corn yield.

At a given rate of fertilization, band versus broadcast placement represents extremes in the actual volume of soil fertilized. The general conclusion that band placement of fertilizer is superior to broadcasting as a means of obtaining maximum plant response has been derived from fertilization practices based on economic considerations. Since much of the research on fertilizer placement has been with low acre-value crops, the rates at which fertilizer was applied were generally low or moderate.

The objectives of the investigations reported here was to test the hypothesis that growth and composition of burley tobacco could be influenced by the volume of soil fertilized when the nutrient concentration covered a wider range than has previously been reported. Since N and P would be expected to react differently when added to soils, these nutrients were chosen for study.

Experimental Procedures

Experiments were conducted in 1961 and 1962 at the Mountain Research Station, Waynesville, North Carolina, on a Hiwassee clay loam. Before the fertilizer was applied, the soil at the site of the 1961 experiment was pH 4.8 and contained 13 ppm P, .33, .79 and .41 me of K, Ca, and Mg, per 100 g of soil, respec-

Table 1. Influence of N rate and placement on livability and growth characteristics of burley tobacco. 1961

Band width in.	N applied, lbs/A 40	80	160	240	320	640
	Replants, %					
8	14	6	14	26	36	
32		4	6	15	20	37
	Plant height, in.[a]					
8	28	29	28	22	24	
32		32	31	28	23	20
	Days to flower[b]					
8	70	69	71	76	76	
32		68	70	70	76	80

[a] *Measurements made 55 days after transplanting.*
[b] *Number days from transplanting until flowers in 50 percent or more of the plants.*

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tively. The soil at the 1962 site was pH 5.9 and contained 21 ppm P, .49, 2.56 and .65 me of K, Ca, and Mg, per 100 g of soil, respectively. Soil pH was determined on a ten g sample with a glass electrode in a 1:1 soil:water suspension. The P, K, Ca, and Mg determinations were made on soil extracts in which the extracting agent was a mixture of .05 *N* HCl and .025 *N* H_2SO_4. The vanadomolybdophosphoric yellow color method was used for the P determinations. Calcium was determined turbidometrically as the oxalate. Mg by the thiozole yellow procedure and K by flame photometry.

A split-plot design with five replications was used for both the N and P treatments. The main plot was fertilizer band width and the sub-plot was rate of nutrient application. Each experimental unit consisted of two rows four feet apart and 25 feet long with plants spaced 15 inches apart.

Rates of N ranged from 40 to 640 lbs/A and rates of P ranged from 22 to 1408 lbs/A. Rates were selected that would permit comparisons between band widths, not only at equal rates, but also at equal concentrations. The two band widths, eight and 32 inches, were obtained by spreading the fertilizer between strings placed the appropriate distance apart. Nitrogen was obtained from ammonium nitrate and P from concentrated superphosphate.

Nutrients other than the one under investigation were applied in a 32-inch band and mixed to the same depth as the one under study. Potassium was applied at the rate of 166 lbs/A each year and Mg at the rate of 60 and 18 lbs/A in 1961 and 1962, respectively. Phosphorus was applied to the N treatments at the rate of 88 lbs/A and N was applied to the P treatments at the rates of 160 and 180 lbs/A in 1961 and 1962, respectively.

The fertilizer nutrients were mixed into the surface six inches of soil with a 40-inch tractor-drawn rototiller centered over each row for the mixing operation. The lateral movement of fertilizer during the mixing operation was approximately one inch to either side of the band.

One to two weeks after the fertilizer was applied, Burley 21 variety tobacco was transplanted at 15-inch hill spacing in the center of the fertilized band of soil. To prevent a major disruption of the fertilizer bands, all cultivation was by hoeing and rototilling.

The tobacco was harvested when judged to be at optimum maturity. Plots that received N at less than 120 lbs/A were cut approximately ten days before those that received N at either 160 or 180 lbs/A. Plots fertilized with N at 240 lbs/A were harvested about 20 days after those that received the 120-pound treatments. All of the P treatments were harvested on the same date.

The cured leaves were stripped from the stalks and placed in farm grades and an official standard grade was assigned to each lot by inspectors of the Agricultural Marketing Service of the USDA. The value per acre was computed by multiplying the acre weight of each grade by the auction average for that grade in the year the crop was grown. The price per 100 pounds was computed from the yield and value per acre for the respective treatments and was used as an index of quality.

The use of fertilizer rates that were not common to both band widths necessitated modification of the conventional split-plot analysis. A "rates within band widths" component accounted for all subplot treatments. The second step of the analysis included only those fertilizer rates present in both band widths.

The influence of fertilizer placement on the distribution and activity of plant roots was studied in 1962 through the use of a radioactive tracer. It was assumed that any treatment effects on root distribution and activity would be reflected by the uptake of the tracer. Nitrogen and P at rates of 120 and 176 lbs/A, respectively, were applied in band widths of eight and 32 inches. Phosphorus was applied to the N plots at the rate of 88 lbs/A, and N to the P plots at

Table 2. Influence of phosphorus rates and placement on growth characteristics of burley tobacco

Year	Band width, in.	P applied, lbs/A 44	88	176	352	704
		Plant height, in.				
1961[a]	8	27	31	30		
	32	26	27	31	34	
1962[b]	8	37	39	40	41	
	32	38	37	39	38	42
		Days to flower[c]				
1961	8	71	70	69		
	32	73	71	69	68	
1962	8	63	60	58	59	
	32	62	62	61	61	57

[a] *55 days after transplanting*
[b] *50 days after transplanting*
[c] *Number days from transplanting until flowers in 50 percent or more of the plants.*

Table 3. Relationship between the appearance of burley tobacco and the manganese content of leaves at different rates and placement of nitrogen

Band width, in.	N Rate, lbs/A	Leaf appearance	Soil pH	Mn in leaf, ppm
8	60	Normal	5.2	165
	240	Normal	5.0	267
	240	Chlorotic	4.8	387
32	120	Normal	4.9	222
	360	Normal	4.5	398
	360	Chlorotic	4.5	585
	480	Normal	4.5	555
	480	Chlorotic	4.4	702
		LSD	.10	112
			.05	135
		CV, %		25

Table 4. Yield, price, value and chemical composition of cured tobacco as influenced by N rate and placement. 1961

Band width, in.	N rate, lbs/A	Yield, lbs/A	Price, dols/cwt	Value, dols/A	Total N, %	Alkaloids %
8	40	1896	66.60	1265	3.11	3.50
	80	2006	66.99	1347	3.23	3.48
	160	2591	67.25	1744	3.93	4.61
	240	2647	64.68	1709	4.21	5.87
	320	2750	63.42	1745	4.64	6.06
32	80	2142	67.47	1445	3.51	3.91
	160	2647	67.63	1790	3.86	4.67
	240	2750	67.29	1851	4.25	5.08
	320	2848	65.73	1873	4.65	4.81
	640	2507	59.95	1508	5.29	6.03
			Between rates within band widths			
LSD	.10	207	1.37	153	.26	.41
	.05	249	1.65	184	.31	.49
			Band width means[a]			
8		2498	65.58	1636	4.00	5.00
32		2597	67.03	1740	4.07	4.62
			Between band width means			
LSD	.10	NS	.79	NS	NS	.34
	.05		1.03			NS
CV, %		7	3	7	6	8

[a] *Only rates common to both band widths are included.*

the rate of 180 lbs/A; in each case, the elements not under investigation were applied in a 32-inch band. Row and plant spacings were the same as previously designed. The treatments were replicated six times and arranged in a randomized block design.

Forty-six days after transplanting, three uniform plants in each replication were selected to receive the radioactive tracer, Rb^{86}. Four vertical holes, six inches deep, were made on each side of the plant with a steel rod one-fourth inch in diameter. The holes were ten inches from the center of the row and three inches apart. Five ml of Rb^{86}-enriched solution of RbCl and five ml of distilled rinse water were introduced into the bottom of each hole through a long-stemmed glass funnel. Thus 40 ml of the RbCl solution for a total Rb^{86} activity of 160 μc were placed within the rooting zone of each plant.

Six days after application of the Rb^{86}, leaf samples were removed from the treated plants. From each plant, two leaves were obtained which were about six inches long at the time the Rb^{86} was applied; these were between the seventh and tenth leaves formed on the plant. The tobacco plants were topped 28 days after the tracer had been applied; and six days later a second sample which consisted of the top leaf was obtained.

The midrib of each leaf was removed, the lamina portion dried at 70°C, weighed and ashed at 500°C. The dry ash was placed in 5 cc plastic vials and activity measurements were made in a scintillation well counter.

Results

Except for short periods of time, climatic conditions were generally favorable for plant growth each year. Unseasonably high temperature and low soil moisture occurred at transplanting time and for several days thereafter in 1961. Soil moisture was limiting toward the end of the growing season in 1962; consequently, harvesting was hastened and the upper leaves did not fully develop.

In **Table 1** data are presented on the influence of N placement and rate on livability and growth characteristics of the plants in 1961. Plant mortality increased as the rate of applied N was increased above 80 lbs/A. At a given rate of N, mortality was greater in the narrow band than in the wide band of fertilized soil. However at equal N concentrations, for example, 80 pounds N in an eight-inch band compared with 320 pounds N in a 32-inch band, mortality was greater in the wide band than in the narrow band. The difference in plant livability between the two band widths became more pronounced as the rate of applied N increased. Conditions were quite favorable for the establishment of seedlings in 1962, and only a few replants were required in any of the treatments.

Plant height was inversely related to the rate of applied N. Application of N in the eight-inch band resulted in slower growth than did an equal rate in the 32-inch band. The time from transplanting to flowering was extended by increasing the rate of N. Plants required longer to flower when N was placed in the narrow band than when the same rate of N was placed in the wide band.

Transplant survival was not different among the P treatments. Data showing the influence of P rates and placement on certain plant growth characteristics are presented in **Table 2.** Plant height approximately eight weeks after transplanting generally increased with increasing rates of P. There was no consistent plant height differences between the two band widths at equal P rates. However, at equal P concentrations in the soil, plant heights were generally greater in the 32-inch band than in the eight-inch band. The time required for the plants to flower was inversely related to the quantity of applied P. At the same rates of P, plants generally required longer to flower when the P was placed in the 32-inch band than in the eight-inch band. In most comparisons, however, at equal concentrations of P, the plants required longer to flower when the P was placed in the eight-inch band rather than the 32-inch band.

About a month after transplanting in 1962, soil moisture became deficient and an abnormal leaf condition developed in certain treatments. It was characterized by rolling at the edges of the leaf and some chlorosis. This condition occurred to a slight extent at N rates of 180 lbs/A in the eight-inch band and 240 lbs/A in the 32-inch band. At higher rates of N, the symptoms were more pronounced and a larger proportion of plants within a plot was affected. When the moisture stress was relieved, the condition disappeared, and no residual effects on the leaves were apparent.

The high soil acidity resulting from nitrification of ammonium from the N fertilizer source could have increased the soluble Mn in the soil;

it was hypothesized that the chlorosis was due to Mn toxicity. To test the hypothesis, leaves were removed from both chlorotic and normal plants 28 days after transplanting and analyzed for Mn. The results in **Table 3** show that in general there was an increase in Mn in the leaves with increasing rates of N. At the same rate of N, the chlorotic plants had a higher Mn content than the normal plants. However, the highest level of Mn in the leaves did not approach 3000 ppm, where Hiatt and Ragland (7) reported the appearance of Mn toxicity symptoms.

There was no significant difference in the Rb^{86} activity in leaves of plants among the different N and P treatments. The lack of differences among treatments indicates that within the sensitivity of the measurements, root activity was similar between the two fertilizer placement procedures. The large coefficients of variation, 60 to 105 per cent, indicate that large differences between treatments would be required to be statistically significant.

Yields, average price, acre values and certain chemical properties of the cured tobacco as influenced by the N treatments are shown in **Tables 4** and 5. There were significant increases in yield as the N rate was increased to 160 lbs/A in 1961 and to 180 pounds in 1962. There were decreases in yields at the 640-pound rate in 1961 and at the 240-pound rate in the eight-inch band in 1962. The latter decrease resulted in the only instance of a significant yield difference between the two band widths at equal N rates.

The quality of the cured tobacco, as measured by the average price, decreased at N rates greater than 160 lbs/A in 1961 and 180 lbs/A in 1962. In 1961, the tobacco grown where the N was placed in the narrow band had a lower average price than that grown in the wide band, with differences becoming greater as the rate of N increased.

The influences of treatments on acre values of the tobacco were similar to their effects on yield. The value of the tobacco increased as the rate of N increased to 160 lbs/A in 1961 to 180 lbs/A in 1962. There were pronounced decreases in values when N was applied at the rate of 640 lbs/A in a 32-inch band in 1961, and 240 lbs/A in an eight-inch band in 1962.

In general, leaf N increased with increases in the rate of applied N. The percent of N in the leaf, however, was not influenced by the placement of the N in the eight- or the 32-inch band widths. Treatment effects on the total alkaloid content were similar to their effects on the N level in the tobacco. Total alkaloid concentration in the leaves generally increased as the rates of N increased to 240 lbs/A. At higher rates, the increase was not so consistent or pronounced.

Yields, average price, value and certain chemical properties of the cured tobacco as influenced by the P treatments are shown in **Tables** 6 and 7. There were no differences among treatments in yield and value except for an anomalous decrease in 1962 at the 88-pound rate in the 32-inch band. The price of the tobacco was not consistently influenced by the P rates. The P content of the cured tobacco generally increased slightly with an increase in the rate of P.

Discussion

At equal rates of N, there were more pronounced differences between the two placements on those criteria of response measured soon after transplanting than those measured after harvest. For example, at equal rates of N, transplant livability and early plant growth were generally greater with the 32-inch than with the eight-inch band but yield and composition of the cured tobacco were not significantly different.

The evidence of better transplant livability and more rapid growth with equal rates of N in the two band treatments suggests that the concentration of N had a role in determining early growth. However, comparisons at concentrations of N theoretically equal in the two band treatments show that transplant livability and plant height were lower in the wider band than in the narrow band. Thus it appears that both the concentration and total quantity of N present had an effect on growth of the young tobacco plants.

Transplant mortality and growth retardation were probably related to N concentrations through its effect on the osmotic pressure of the soil solution. Sufficient information was not obtained to relate quantitatively the osmotic pressure of the soil solution to growth of burley tobacco. In 1961, however, there were indications that a salt concentration which gave a conductivity of 4.77 mmhos per cm in a saturation extract from the soil surrounding the roots of recent transplants was sufficient to reduce plant livability. This salt concentration was obtained with N at the rate of 240 lbs/A placed in a 32-inch band.

There are at least two theories on

Table 5. Yield, price, value and chemical composition of cured tobacco as influenced by N rate and placement. 1962

Band width, in.	N rate, lbs/A	Yield, lbs/A	Price, dols/cwt	Value, dols/A	Total N, %	Alkaloids %
8	60	2347	65.58	1540	3.51	4.19
	90	2471	66.47	1644	3.78	4.54
	120	2561	66.81	1711	3.89	4.36
	180	2810	67.17	1887	4.38	4.68
	240	2598	63.86	1659	4.42	5.34
32	120	2574	66.44	1710	3.80	4.27
	180	2836	66.89	1896	4.10	4.55
	240	2943	64.33	1893	4.37	5.64
	360	2931	62.46	1832	4.83	5.43
	480	3009	62.69	1886	5.02	5.25
			Between rates within band widths			
LSD	.10	143	1.03	105	.25	.55
	.05	172	1.24	126	.30	.66
			Band width means[a]			
8		2656	65.95	1752	4.23	4.79
32		2784	65.89	1833	4.09	4.82
			Between band width means			
LSD	.10	93	NS	NS	NS	NS
	.05	NS				
CV, %		5	1	5	5	11

[a] *Only rates common to both band widths are included.*

Table 6. Yield, price, value and chemical composition of cured tobacco as influenced by P rate and placement. 1961

Band width, in.	P rate, lbs/A	Yield, lbs/A	Price, dols/cwt	Value, dols/A	Total P, %	Alkaloids %
8	22	2587	67.31	1741	.19	4.69
	44	2504	67.78	1696	.18	4.79
	88	2491	67.18	1673	.20	4.66
	176	2626	67.74	1780	.19	4.76
32	44	2585	68.07	1760	.19	4.54
	88	2537	67.61	1717	.19	4.57
	176	2620	67.98	1782	.20	4.94
	352	2706	67.16	1817	.21	4.77
		Between rates within band widths				
	LSD .10	NS	NS	NS	.01	NS
	.05				.01	
		Band width means[a]				
8		2540	67.56	1717	.19	4.74
32		2581	67.88	1753	.19	4.68
		Between band width means				
	LSD .10	NS	NS	NS	NS	NS
	CV, %	7	1	7	4	6

[a] *Only rates common to both band widths are included.*

Table 7. Yield, price, value and chemical composition of cured tobacco as influenced by P rate and placement. 1962

Band width, in.	P rate, lbs/A	Yield, lbs/A	Price, dols/cwt	Value, dols/A	Total P, %	Alkaloids %
8	44	2826	66.41	1878	.21	4.94
	88	2810	66.56	1871	.21	4.65
	176	2742	66.71	1829	.22	4.79
	352	2817	66.87	1884	.22	4.93
32	44	2853	66.68	1902	.21	4.88
	88	2700	66.33	1791	.22	4.48
	176	2906	67.07	1949	.21	4.95
	352	2918	66.79	1949	.22	5.01
	704	2875	67.10	1929	.23	5.12
	1408	2910	67.40	1961	.26	5.09
		Between rates within band widths				
	LSD .10	116	.57	93	.01	NS
	.05	140	NS	112	.01	
		Band width means[a]				
8		2799	66.64	1865	.22	4.83
32		2844	66.72	1898	.21	4.83
		Between band width means				
	LSD .10	NS	NS	NS	NS	NS
	CV, %	5	1	4	3	10

[a] *Only rates common to both band widths are included.*

the relationship of maximum crop yields and the volume of soil fertilized. One proposal is that maximum yields obtained by mixing nutrients with a large volume of soil are potentially greater than those obtained by mixing the nutrients with a relatively small volume. Another hypothesis is that maximum yields are potentially the same from both methods of placement, but that less fertilizer is required when the small volume is utilized. The results of the experiments on N reported here do not fit either theory. From the data, it appears that the maximum yield for both placement procedures was the same and that there was no difference between the two placements in the amount of N required to reach maximum yields.

The content of total alkaloids and total N in the cured leaf can be nsed as indicators of the relative quantity of N available to the plants. As a general rule, when more N is available to the plants, there is an increase in total alkaloids and total N in the cured leaf. Exceptions would be expected when the N supply became sufficiently excessive to interfere with plant growth. The data indicate that the quantity of N available to the tobacco was the same, regardless of fertilized band width, because the total alkaloid and total N content of the cured leaves were similar when comparing the two band widths.

If root extensiou was increased as the width of the fertilizer band increased, then greater nutrient uptake and, possibly, plant growth would be expected with the wide than with the narrow band. However, data from the Rb^{86} experiment show that the measured activity of the leaves was not different between N placements. Most of the alkaloids in tobacco are synthesized in the roots; Wolf and Bates (14) have shown that the size of the root system is correlated with the alkaloid (nicotine) content of the plant. The total alkaloid content of the cured leaves was not different between band widths, thereby providing further evidence that root extension was not promoted by wider placement of the N.

Root extension was apparently not measurably affected by the placement of N and the quantity of N absorbed was about eqnal, whether it was placed in an eight- or a 32-inch band. The reasons that the two volumes of soil were equally effective in providing N to the tobacco are perhaps related to the mobility of the NO_3 ion in the soil, to its ease of absorption and to rapid translocation in the plant. A projection of the findings of Barber (2) and Vasey and Barber (13) supports this reasoning. These workers found that in field experiments banded K was as effective as that broadcast, a factor which they related to the mobility of K in the soil. They also found that Rb^{86}, often used as a proxy for K, was mobile in the soil. Eaton and Bernardin (6) visualized Cl moving by mass-flow to the roots and becoming more concentrated in the vicinity of the roots.

These findings are applicable to the results obtained in this investigation because NO_3 is more mobile in the soil than K and about equal to Cl. Thus because of ease of mobility, NO_3 could move to the roots as water was extracted from the soil; or the ions could move by diffusion in the soil solution. The results would be that the NO_3 would no longer be confined to the exact location where it had been applied. Also, the ready absorption and translocation of NO_3 in the plant would allow considerable removal of N by a relatively small part of the root system. Vasey and Barber (13) attributed the effectiveness of banded Rb^{86} partly to its rapid uptake and translocation by the plant. Such phenomena allow a greater uptake of the nutrients per unit of root area with band than with broadcast placement.

Furthermore, the presence of N throughout the soil is not a requirement for the entrance and growth of roots in all parts of the media. Any nitrogenous material used by roots growing in soil not containing N can apparently be supplied by translocation from other parts of the plant.

There were only a few instances of differential plant response to rates of P. One of these responses was a stimulation of early growth with increasing amounts of applied P. At equal rates of P below 352 lbs/A, the height of plants after about eight weeks of growth was greater in the eight-inch than in the 32-inch band. Such an observation is not unusual, since it is often reported that banded P promotes earlier growth than broadcast P. It is generally accepted that greater concentrations of P are needed in the soil before the plant root system becomes extensive. After the roots have extended throughout the soil, the band of P becomes less important, because a lower concentration of P in the entire rooting volume can supply more of the nutrient to the plant than a higher concentration in a restricted volume.

Tobacco yields were not different among the P treatments. All of the soils used in the study had a P content that exceeded 12 ppm before initiation of the treatments. At a lower level of soil P, a yield response to fertilizer P would have been more probable.

Summary

Field experiments were conducted in 1961 and 1962 on the Mountain Research Station at Waynesville, North Carolina, to test the hypothesis that the volume of soil enriched with different quantities of N and P would influence their effects on the growth of burley tobacco. Nitrogen at rates ranging from 40 to 640 lbs/A was placed in bands of either eight or 32 inches and mixed with the surface six inches of soil. A similar arrangement was used with P, except that rates of P ranged from 22 to 1408 lbs/A. All nutrients except the one being evaluated were applied at a constant rate and in a 32-inch band.

Differential responses to the volume of N-enriched soil were more evident soon after transplanting than at the time of harvest. Yields and chemical composition of the cured leaf were usually influenced more by the rate of N than by differences in the volume of soil fertilized. The lack of differences in yield between the two placement procedures is believed to be due to the mobility of N in the soil, the rapid uptake and translocation of N and the lack of differences in root growth between the two placements.

Early growth of the tobacco was stimulated more when P was placed in the eight-inch than in the 32-inch band. There were no differences among P rates or placement on yield or quality of the cured tobacco. This effect is assumed to be due to the residual level of P in the soil.

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