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FERTILIZER STUDIES with VEGETABLE CROPS on REPRESENTATIVE SOILS in ALABAMA

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FERTILIZER STUDIES with VEGETABLE CROPS on REPRESENTATIVE SOILS In ALABAMA

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NO OTHER GROUP of crops requires as much fertilizer as vegetables require. Use of commercial fertilizers in the production of vegetable crops is very necessary in the South where soils are low especially in available phosphorus and nitrogen.

Results reported in this bulletin are from experiments involving use of commercial fertilizers on the principal vegetable crops grown on different soils of the State. Results of studies presented here are confined to the three elements — nitrogen, phosphorus, and potash—which constitute what is generally referred to as a complete fertilizer.

REVIEW OF LITERATURE

NEED AND USE OF COMMERCIAL FERTILIZERS IN THE SOUTH

Use of commercial fertilizers in the United States is relatively old. Commercial fertilizers have played an important part especially in the agriculture of the South. During the last 50 years, the South has consumed two-thirds or more of the total amount of fertilizers used in the United States. In recent years, however, the proportion of national tonnage used by the South has declined, even though the actual quantity consumed has continued to increase. This decline is the result of increased use of commercial fertilizers in other sections of the country.

While the acreage of truck crops in the United States is small in comparison to that of field crops, the proportion of the ferti-

*The outlying experiments reported in this bulletin were done under the supervision of Otto Brown, Harold Yates, Fred Stewart, R. C. Christopher (resigned), T. P. Whitten, J. W. Williamson, J. W. Richardson, and Robert Taylor (resigned) of the Agricultural Experiment Station staff.

lizer used on truck crops is relatively large. For instance, in 1946 the 67.2 million acres of wheat were fertilized with 1.08 million tons of fertilizer, which was an average rate of 32 pounds per acre. On the other hand, 1.0 million tons of fertilizer were applied to 2.6 million acres of potatoes; this was an average acre rate 769 pounds. In the same year, 88.7 million acres of corn were fertilized with 3.2 million tons of fertilizer, which was about 72 pounds per acre, whereas 1.6 million tons were used on 4.1 million acres of vegetable crops, or the average was 780 pounds per acre.

Fertilizers are important in the South because the soils are low in certain plant foods, which must be supplied if profitable production is obtained. To supply such needs, makes the cost relatively high. In 1945, the South used approximately 8.5 million tons of fertilizer at a value of about 350 million dollars.

Pierre *(13)* has pointed out the important role of phosphorus in plant nutrition and has discussed the importance of phosphorus fertilization. Scarseth and Tidmore *(14, 15)* reported that soils of the South were low in available phosphorus and had high phosphorus-fixing power.

Fudge *(7)* showed that acid-forming nitrogenous fertilizers caused a marked decrease in phosphate availability and an increase in water-soluble potassium. He also showed that physiologically basic fertilizers caused an increase in phosphate availability and a reduction in water-soluble potassium.

Studies of soils in the various sections of the United States have revealed that soils of the South have low amounts of organic matter and nitrogen *(1)*. Jenny *(9)* found that the nitrogen and organic content increased 2 to 3 times for each 10° C fall in temperature provided the precipitation-evaporation ratio was constant. He found that the average soil in Canada contained about 0.4 to 0.5 per cent nitrogen, in Iowa and Minnesota about 0.2 to 0.3 per cent, and in Louisiana about 0.05 per cent.

The reasons for the low amount of nitrogen and of available phosphorus are well established. The South has long seasons of high temperature and high rainfall. Decomposition of organic matter is rapid and loss by leaching of the nitrogen released is high. High rainfall, likewise, causes high loss of minerals, especially magnesium and calcium. Midgley *(12)* and Scarseth *(16)* showed that the loss of magnesium and calcium resulted in an increase in the proportion of aluminum and iron, which causes a decrease in the availability of phosphorus in the soil.

Cooper and others *(5)* reported that the amount of potash, especially in heavier soils, will often amount to 10 to 20 times the quantities of nitrogen or phosphorus. They also pointed out that it is not necessary to have as high a level of potassium in sandy soils of the Coastal Plain as in the soils of the Corn Belt.

Many investigators have studied the basic principles governing fixation of applied phosphorus. Scarseth and Tidmore *(14, 15)* and Scarseth *(16)* found that the efficiency of phosphorus decreased with the time of contact with the soil. They also found that the phosphorus-fixing capacity of soil colloids varied inversely with the silica-sesquinoxide ratio of the colloid. Bryan *(2)*, Bushnell *(3)*, Hawkins *(8)*, Ware and others *(19)*, and Ware and Johnson *(21)* showed that there is an accumulation of phosphorus on heavily fertilized soils and that it is available to crops in later years. From these studies, it appears much may be done in more efficient use, especially of phosphorus.

In view of the need in the South to correct certain soil deficiencies by use of commercial fertilizers and in view of the relatively high costs involved, the importance of determining the proper fertilizer for those crops grown in quantity is apparent.

Experiments Dealing with Fertilizers for Vegetable Crops

For some important truck crops, fertilizer needs have been fairly well established on the more important soils. Some work has been conducted with almost all vegetable crops at least on a few soils.

Lloyd and Strubinger *(10)* conducted fertilizer experiments with 25 different vegetable crops in Illinois. They obtained increases sufficient to recommend phosphorus applications in addition to manure and limestone for only nine crops and potash applications in addition to phosphorus, limestone, and manure for only seven crops.

Cooper and Watts *(6)* in fertilizer tests in Arkansas with five vegetable crops on two different soils found that phosphorus gave greater yield increases than nitrogen on one soil and increases about as large as nitrogen on a second soil. Yield increases were usually much less from potash.

Mack *(11)* in his studies on application of phosphorus, nitrogen, potash, and organic materials to cabbage, tomatoes, and

potatoes found that the response to phosphorus applications was most striking.

Skinner and Ruprecht *(17)* reported that the fertilizer grade giving best results for tomatoes on Calcareous Glade soils of Florida, contained 4 to 6 per cent ammonia, 6 to 8 per cent phosphoric acid, and 6 to 8 per cent potash. He also found that when the nitrogen need of celery is satisfied potash is effective in producing yield of good quality. Celery gave little response to phosphorus applications.

White and Boswell *(23)* pointed out that manure produces the desired yields, but does so at high cost if it must be purchased.

Carolus *(4)*, in his work showed that the potato has its maximum nutrient requirement between the 50th and 80th days. In 1936 during the 30-day maximum-absorption period, an acre of potatoes absorbed at the following rates per day: 1.66 pounds of nitrogen, 0.3 pounds of phosphorus, and 3.33 pounds of potash.

LOCATION, SOILS, CROPS, AND METHODS

Field Bins

Much of the work reported here was done at the Main Station, Auburn, and most of these experiments were conducted in concrete field bins, each 1/640-acre in size. The bottoms of the bins were open, and the introduced soils rested on the local subsoil, which was a sandy clay of Piedmont origin.

The soils used in the bins were Norfolk, Cecil, Eutaw, Decatur, Hartsells, and Chesterfield, which are representative of the Coastal Plain Region, Piedmont Plateau, Black Belt, Limestone Valley, Appalachian Plateau, and Piedmont-Coastal Plain transition, respectively. The Norfolk and Chesterfield soils were local, whereas the Cecil, Eutaw, Decatur, and Hartsells soils were introduced.

The soils selected varied considerably in physical and chemical properties. The Norfolk soil was a sandy loam, Cecil a sandy clay, Eutaw a clay, Decatur a clay, Hartsells a fine sandy loam, and Chesterfield a loamy sand.

Separate studies of nitrogen, phosphorus and potash were conducted in the first sets of bins constructed in 1933. In the newer sets of bins, built in 1938, studies of the three elements were combined into fertilizer grade experiments. In the first sets of bins, 15 vegetables were grown each year. Fertilizer treatments

included five rates of nitrogen and phosphorus, and four rates of potash. The crops were rotated from section to section in succeeding years. Three successive crops were grown each year in each section. In the fertilizer grade studies, only two successive crops were grown each year.

When each element was varied, standard rates of the other two elements were used. The standard rates were 160 pounds per acre of P_2O_5 on Norfolk and Hartsells soils, and 320 pounds per acre on Cecil, Eutaw, and Decatur soils. The standard rate of potash was 135 pounds per acre and of nitrogen 90 pounds per acre on all soils. Where two successive crops were grown on the same soil the same year, one-half of the standard rates of phosphorus and potash were applied to each crop, or where three crops were grown, one-third was applied to each crop. The full amount of nitrogen was applied to each crop.

All phosphorus and potash and a portion of the nitrogen were applied 10 to 14 days before planting. On the older sets of bins containing Norfolk, Eutaw, and Cecil soils, one-half of the nitrogen was applied with the phosphorus and potash; the other half was used as a side dressing 2 to 4 weeks after crops were up to a stand. Superphosphate was used as the source of phosphorus and muriate of potash as the source of potassium. Nitrate of soda or a combination of nitrate of soda and ammonium sulphate was used as a source of nitrogen.

The position of the rows remained about the same from year to year. During the course of the experiment, 27 different vegetable crops were studied in the phosphorus, nitrogen, and potash series in the old plots. From 7 to 13 crops were included in the fertilizer grade studies in the new bins.

As previously reported *(20)*, field bins used in this study were satisfactory as compared to field plots. Results from the basic study of phosphorus utilization have been published by this Station *(21)*. Earlier reports *(18, 22)* based on results from these studies have been issued.

Field Plots

At the Gulf Coast Substation, Fairhope, fertilizer studies were conducted with the more important commercial truck crops grown in the Gulf Coast area. The experiments were on Norfolk and Orangeburg soils.

Fertilizer experiments were conducted with potatoes, cabbage,

and sweetpotatoes on Decatur soil at the Tennessee Valley Substation, Belle Mina, and on Hartsells soil at the Sand Mountain Substation, Crossville. Sweetpotato fertilizer studies on Norfolk and Orangeburg soils were carried on at the Brewton and Monroeville Experiment Fields, respectively; on Red Bay soil at the State Farm, Atmore; and on a Chesterfield soil at the Main Station, Auburn. Cooperative field experiments with fertilizers involving a number of vegetable crops were conducted on a Ruston soil at Thorsby.

In field plots only one record crop was grown each year and the full annual application of all three elements was applied to the one crop.

Calculation of Returns

In the final analysis, the farmer measures the value of a fertilizer in dollars returned for dollars spent. Occasionally relationships are pointed out between the amount and value of increased yield from different fertilizer increments and cost of increments. Fertilizer costs are based either on the highest price or the price range during the past 20 years. Values for the products are assumed.

PRESENTATION OF DATA

Location, type of plot used, soil type, rates of application of the three major elements, average number of years, and crop yields are presented in the tables.

Comparative Response of Vegetable Crops to Nitrogen, Phosphorus, and Potash

In Tables 1, 2, and 3 are given the average relative yields of a large number of vegetable crops grown on a number of different soils when receiving different rates of nitrogen, phosphorus, and potash. The yields are expressed in percentage of the yields from the highest rates of each element.

The Norfolk, Eutaw, and Cecil soils used in the studies of single elements were soils that had received low fertilizer rates or no fertilizers in previous years. The Hartsells, Decatur, and Chesterfield soils had been used in recent years for growing field

crops and had received applications of fertilizers commonly used on general field crops.

Yields at the zero rates of nitrogen, phosphorus, and potash reflect past fertilizer treatments to a large exent. On the soils to which no fertilizers or small amounts had been applied in recent years, phosphorus appeared to be the most limiting factor and nitrogen second. The response to potash was small. The average relative yields of 26 crops in the no-phosphorus treatments were only 31 per cent on Norfolk soil, 14 per cent on Eutaw soil and 8 per cent on Cecil soil. In the no-nitrogen treatments, the average relative yield of 27 crops was 27 per cent on Norfolk soil. The average relative yields of 25 vegetable crops in the no-

TABLE 1. RELATIVE YIELDS OF VEGETABLE CROPS FROM INCREASED APPLICATIONS OF NITROGEN ON DIFFERENT SOILS, FIELD BINS, MAIN STATION, AUBURN, ALABAMA, 1933-42

Nitrogen (N) applied per acre[1]	Yields in per cent of that from maximum nitrogen rate[2]				
	Norfolk	Hartsells	Decatur	Chesterfield (A)[3]	Chesterfield (B)[3]
Pound	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
0	27	33	40		
30	58	62	65		
60	79	81	81		
90	93	95	93		
120[4]	100	100	100		
0				42	
40				81	
60				95	
80[4]				100	
0					11
60					75
80					95
100					106
120[4]					100

[1] Amount applied to each of three crops grown each year on the Norfolk and to each of two crops per year on the Hartsells, Decatur, and Chesterfield soils. Amounts of phosphorus and potash considered necessary for maximum yields were added to all treatments.

[2] Number of crops on Norfolk 27, on Hartsells 11, on Decatur 12, on Chesterfield (A) 9, and on Chesterfield (B) 4. Percentages under each soil were calculated from combined total yields for all crops grown on that particular soil.

[3] Chesterfield soil (A) represents area of medium fertility; Chesterfield soil (B) represents area of low fertility.

[4] Maximum rate.

potash treatments were 85 and 89 per cent, respectively, on Norfolk and Cecil soils.

On soils that had received usual amounts of fertilizers for field crops in recent years, average relative yields of plots receiving no phosphorus ranged from 40 to 49 per cent, those receiving no

TABLE 2. RELATIVE YIELDS OF VEGETABLE CROPS FROM INCREASED APPLICATIONS OF PHOSPHORUS ON DIFFERENT SOILS, FIELD BINS, MAIN STATION, AUBURN, ALABAMA, 1933-42

Phosphorus (P_2O_5) applied per acre[1]	Yields in per cent of that from maximum phosphorus rate[2]					
	Norfolk	Eutaw	Cecil	Chesterfield	Decatur	Hartsells
Pound	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
0	31					
13.33	73					
26.67	91					
40.00	100					
53.33[3]	100					
0		14	8			
26.67		75	72			
53.33		89	92			
80.00		98	98			
106.67[3]		100	100			
0				45		
60				92		
80				91		
100				101		
120[3]				100		
0					40	
40					95	
80					104	
120					101	
160[3]					100	
0						49
20						82
40						97
60						101
80[3]						100

[1] Amount of phosphorus applied to each of three crops grown each year on the Norfolk, Eutaw, and Cecil soils and to each of two crops on the Chesterfield, Decatur and Hartsells soils. Amounts of nitrogen and potash considered necessary for maximum yields were added to all treatments.

[2] Number of crops on Norfolk, Eutaw, and Cecil 26, and on Chesterfield 7, on Decatur 12, and on Hartsells 11. Percentages under each soil were calculated from combined total yields of all crops grown on that particular soil.

[3] Maximum rate.

TABLE 3. RELATIVE YIELDS OF VEGETABLE CROPS FROM INCREASED APPLICATIONS OF POTASH ON DIFFERENT SOILS, FIELD BINS, MAIN STATION, AUBURN, ALABAMA, 1933-42

Potash (K_2O) applied per acre [1]	Yields in per cent of that from maximum potash rate [2]				
	Norfolk	Cecil	Decatur	Hartsells	Chesterfield
Pounds	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
0	85	89			
15	117	99			
30	94	103			
45 [3]	100	100			
0			82	82	
22.5			93	92	
45.0			95	101	
67.5 [3]			100	100	
0					72
40					96
60					101
80 [3]					100

[1] Amount applied to each of three crops grown each year on Norfolk and Cecil soil and to each of two crops per year on other soils. Amounts of phosphorus and nitrogen considered necessary for maximum yields were added to all treatments.

[2] Number of crops on Norfolk and Cecil 25, on Decatur 12, on Hartsells 11, and on Chesterfield 13. Percentages under each soil were calculated from combined total yields for all crops grown on that particular soil.

[3] Maximum rate.

nitrogen ranged from 11 to 42 per cent, and those receiving no potash ranged from 72 to 82 per cent.

Irrespective of past fertilizer treatments, small applications of phosphorus and potash satisfied more quickly the requirements of vegetable crops for maximum or near-maximum yields than small applications of nitrogen. Applications of phosphorus as low as 26.67 pounds per acre of P_2O_5 gave yields that were 72 to 91 per cent as high as those from the highest phosphorus rates. Treatments of 40 to 53.3 pounds per acre of P_2O_5 resulted in yields of 89 to 100 per cent of those from the highest rates. Potash applications of 15 pounds per acre on Norfolk and Cecil soils gave yields as high as the highest rates, while applications of 22.5 pounds on Decatur and Hartsells soils gave relative yields of 93 and 92 per cent, respectively. Considerably higher amounts of nitrogen were required to give maximum or near-maximum yields.

Applications of 30 pounds per acre of nitrogen gave relative yields of only 58 to 64 per cent. Relative yields from the 60-pound rate ranged from 75 to 81 per cent on all soils except one, in which case a higher yield was obtained. Applications of 80 to 90 pounds per acre gave relative yields of 93 per cent or higher. Increases in relative yields of 5 to 7 per cent were obtained from applications up to 120 pounds per acre on three soils, and up to 100 pounds on one soil.

Studies in Field Bins with Indivdual Elements for Different Crops on Different Soils

Phosphorus Studies on Norfolk, Eutaw, and Cecil Soils

Results of the phosphorus phase of the study are presented in Table 4. The yields of 24 different vegetable crops grown on three soils of radically different physical and chemical characteristics and fertilized at five different rates of phosphorus are given in the table.

In a companion study (21), great differences were found among vegetables in their phosphorus requirements, phosphorus-feeding capacities, phosphorus-utilization efficiencies, and responses to increased applications of phosphorus.

Crops differed greatly from each other in their ability to get phosphorus when none was added and in their need for phosphorus for maximum production on different soils. These differences may be observed by comparing the total yields of beans and lima beans from different rates of phosphorus, Table 4, page 13. The total yields of beans on the Norfolk soil were increased more than 2.5 times by increasing the application of phosphorus. On the other hand, phosphorus did not increase the yields of lima beans grown on the Norfolk soil.

Continuing the comparison, it may be observed that on the Eutaw soil, the total yield of beans was increased over 5 times from applications of phosphorus, and on the Cecil almost 15 times, whereas the total yields of lima beans were increased only a fourth on the Eutaw soil and only two times on the Cecil soil.

The contrast in response of crops to phosphorus on different soils is illustrated still further by the yields of beets, Table 4, page 13. It may be observed that the yields of beet roots were increased about 10 times on the Norfolk soil, 85 times on the

TABLE 4. YIELDS OF DIFFERENT VEGETABLE CROPS FROM APPLICATIONS OF DIFFERENT AMOUNTS OF PHOSPHORUS ON DIFFERENT SOILS, FIELD BINS, MAIN STATION, AUBURN, ALABAMA

P_2O_5 applied per acre to each crop [1]	Yields per acre														
	Beans (4-yr. av.)		Lima Beans (4-yr. av.)		Beets (3-yr. av.)		Chinese Cabbage (3-yr. av.)	Cabbage (4-yr. av.)		Carrots (4-yr. av.)			Chard (4-yr. av.)	Collards (4-yr. av.)	
	Early and med.	Total	Early and med.	Total	Roots	Total	Total	Heads	Total	Roots	Market-able	Total	Total	Early and med.	Total
Lb.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
							Norfolk Soil								
0	28	72	156	213	10	1,815	6,184	2,680	10,860	2,537	1,770	6,028	807	1,453	1,549
13.33	58	132	157	207	71	8,445	24,943	9,180	20,080	4,812	4,444	10,825	7,158	8,120	10,613
26.67	91	153	145	193	85	9,912	35,347	14,040	26,820	7,115	9,244	14,999	12,288	11,229	13,970
40.00	116	175	154	203	101	10,958	37,685	14,740	27,360	8,935	11,400	18,464	14,403	11,567	15,164
53.33	127	190	161	205	104	11,066	36,203	13,760	27,260	9,082	11,667	18,166	14,447	11,525	14,929
							Eutaw Soil								
0	35	53	124	167	2	286	1,489	110	2,860	3,825	2,655	8,346	560	178	256
26.67	114	152	172	200	62	7,829	31,223	14,160	27,000	8,289	10,803	16,441	3,983	15,106	20,445
53.33	164	211	187	211	116	12,662	36,002	18,220	32,520	9,977	13,785	19,620	5,543	18,636	24,505
80.00	199	250	183	205	154	15,969	38,908	18,900	33,120	11,679	17,240	22,383	8,195	20,354	25,978
106.67	224	273	188	211	170	16,948	41,146	19,540	35,400	12,303	18,881	23,559	8,781	21,116	26,908
							Cecil Soil								
0	6	10	54	96	1	447	962	0	1,280	1,370	1,010	3,234	643	119	172
26.67	41	66	90	145	90	9,352	26,731	7,980	19,380	5,588	6,592	11,671	10,559	10,477	14,098
53.33	71	98	119	170	154	16,322	34,087	13,200	27,500	10,344	14,744	20,005	15,380	13,945	18,755
80.00	97	136	135	190	169	16,316	34,118	14,060	28,880	11,786	17,239	22,300	17,905	14,715	19,247
106.67	107	148	148	201	168	16,624	31,077	14,520	30,020	11,458	17,521	22,809	20,738	14,591	19,441

(*Continued*)

[1] Amount of phosphorus applied to each of three crops grown on same land the same year; 90 pounds per acre of N and 45 pounds per acre of K_2O were applied to all treatments.

TABLE 4. (*Continued*) YIELDS OF DIFFERENT VEGETABLE CROPS FROM APPLICATIONS OF DIFFERENT AMOUNTS OF PHOSPHORUS ON DIFFERENT SOILS, FIELD BINS, MAIN STATION, AUBURN, ALABAMA

P_2O_5 applied per acre to each crop [1]	Yields per acre										
	Eggplant (3-yr. av.)	Kale (4-yr. av.)	Lettuce (4-yr. av.)	Pepper (2-yr. av.)	English Peas (4-yr. av.)	Potatoes (4-yr. av.)		Okra (2-yr. av.)	Onion (4-yr. av.)	Radish (4-yr. av.)	
	Total	Total	Total	Total	Total	Marketable	Total	Total	Total	Roots	Total
Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Bu.*	*Bu.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
					Norfolk Soil						
0	2,230	410	756	5,257	591	47	93	3,669	1,205	1,495	2,617
13.33	15,745	4,178	4,227	12,009	1,553	69	123	3,937	3,145	3,977	6,404
26.67	20,104	6,420	6,820	13,501	2,153	93	147	5,039	5,236	4,729	6,767
40.00	18,882	7,889	7,787	19,224	2,354	106	158	3,596	6,962	4,592	7,234
53.33	20,868	8,079	8,169	16,490	2,405	117	164	4,520	6,665	4,236	6,736
					Eutaw Soil						
0	2,333	251	393	7,387	1,301	55	79	3,587	1,856	533	1,042
26.67	20,824	6,182	3,023	17,090	3,532	117	148	5,252	4,368	5,938	9,138
53.33	20,133	8,951	5,009	19,600	3,609	181	216	5,312	8,365	6,815	10,502
80.00	25,269	10,377	8,253	23,104	3,679	203	245	5,693	9,789	6,698	10,483
106.67	24,940	11,160	9,349	30,405	3,599	203	251	6,482	10,581	6,102	9,524
					Cecil Soil						
0	519	132	755	2,015	571	24	45	1,443	876	176	573
26.67	9,229	5,939	4,309	14,639	2,780	89	123	3,386	4,067	3,880	6,025
53.33	11,846	7,324	8,192	17,511	3,780	125	165	5,245	7,243	4,140	6,523
80.00	16,020	7,705	10,444	19,318	3,640	138	180	4,994	9,481	4,112	6,400
106.67	18,409	8,525	13,599	20,467	3,887	156	196	4,676	9,306	4,127	6,733

(*Continued*)

[1] Amount of phosphorus applied to each of three crops grown on same land the same year; 90 pounds per acre of N and 45 pounds per acre of K_2O were applied to all treatments.

TABLE 4. (*Continued*) YIELDS OF DIFFERENT VEGETABLE CROPS FROM APPLICATIONS OF DIFFERENT AMOUNTS OF PHOSPHORUS ON DIFFERENT SOILS, FIELD BINS, MAIN STATION, AUBURN, ALABAMA

P_2O_5 applied per acre to each crop [1]	Yields per acre										
	Rutabaga (2-yr. av.)		Squash (4-yr. av.)	Sweetpotatoes (4-yr. av.)		N. Z. Spinach (4-yr. av.)	Tender-green (4-yr. av.)	Tomatoes, sum. (3-yr. av.)		Turnips (4-yr. av.)	
	Roots	Total	Total	Market-able	Total	Total	Total	Early and med.	Total	Roots	Total
Lb.	*Lb.*	*Lb.*	*Lb.*	*Bu.*	*Bu.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
					Norfolk Soil						
0	11,872	20,122	2,374	342	469	4,471	4,149	1,068	3,367	5,037	13,648
13.33	27,399	49,107	9,284	426	495	13,370	10,921	3,113	6,268	10,652	27,224
26.67	32,080	57,709	16,832	429	571	16,300	13,903	5,461	10,862	11,680	30,359
40.00	33,332	58,640	16,355	385	447	18,396	13,514	8,264	12,647	11,740	29,985
53.33	34,365	59,661	18,542	422	500	19,027	12,096	8,920	14,912	12,074	31,152
					Eutaw Soil						
0	2,432	4,816	1,096	346	453	511	142	370	1,020	1,091	3,438
26.67	31,185	55,441	10,280	331	428	24,216	17,457	3,778	7,022	13,035	36,225
53.33	32,749	59,732	14,118	367	440	27,341	19,521	6,927	12,889	14,778	42,529
80.00	33,543	59,424	16,464	370	444	31,047	21,421	10,207	18,401	15,601	45,108
106.67	32,534	57,968	16,650	359	453	29,244	21,134	9,329	18,110	14,598	42,583
					Cecil Soil						
0	506	1,379	8	157	227	261	161	86	455	262	835
26.67	34,109	61,840	6,661	259	376	16,415	12,246	2,115	5,728	9,832	26,858
53.33	34,180	62,416	11,124	311	392	18,172	14,148	4,467	8,613	11,350	31,672
80.00	34,278	62,064	12,063	368	436	22,575	15,746	2,357	8,009	12,522	35,106
106.67	36,199	64,640	12,806	286	399	17,584	15,308	4,457	12,084	11,745	34,207

[1] Amount of phosphorus applied to each of three crops grown on same land the same year; 90 pounds per acre of N and 45 pounds per acre of K_2O were applied to all treatments.

Eutaw soil, and 168 times on the Cecil soil by the highest applications of phosphorus.

Crops differ in a third important respect in the way they respond to phosphorus. With some crops very large increases resulted from small applications of phosphorus, but further increases were relatively small from the higher rates. For instance, the yield of turnips from the no-phosphorus treatment was 1,091 pounds of roots on the Eutaw soil, Table 4, page 15. This yield was increased 12 times by application of 26.67 pounds per acre of P_2O_5. At the higher rates of phosphorus, the yield increased only from 13,035 to 15,601 pounds per acre. In contrast, the yield of lettuce increased materially at each higher rate of phosphorus, Table 4, page 14.

The response of each crop to phosphorus is shown by the data in the tables. Since the amounts of phosphorus added represent those applied to each of three crops grown each year on the same area and since crops consumed only a portion of the amounts added, each crop had the benefit of at least a portion of the phosphorus added to previous crops *(21)*.

The cost range during the past 20 years for each increment of phosphorus on the Norfolk soil was approximately $.54 to $.93, and on the Eutaw and Cecil soils it was $1.08 to $1.87.

Some idea of returns from expenditures for phosphorus may be obtained from data on peppers grown on the Eutaw soil (Table 4). Assuming a maximum cost of $1.87 for each increment of phosphorus and assuming a value of 2-1/2 cents per pound for pepper, the value of the increased yield per $1 of cost from the first increment was about $130, from the second about $34, from the third about $47, and from the fourth about $98.

Nitrogen Studies on Norfolk Soil

The nitrogen studies in the older bins were confined to one soil type. The yields of 27 different vegetable crops from applications of five different rates of nitrogen on a Norfolk soil are given in Table 5. The rates of application consisted of 0, 30, 60, 90, and 120 pounds per acre of nitrogen. The cost range of each increment was $2.50 to $6.30.

Yields of the different crops in most instances increased with each increment of nitrogen applied up to the full rate of 120 pounds per acre. However, most crops at the 90-pound rate reached yields 90 to 95 per cent of those from the maximum nitrogen rate.

TABLE 5. YIELDS OF DIFFERENT VEGETABLE CROPS GROWN ON NORFOLK SOIL FROM APPLICATION OF DIFFERENT AMOUNTS OF NITROGEN, FIELD BINS, MAIN STATION, AUBURN, ALABAMA

Crop	Yield per acre on Norfolk soil from different rates of N [1]				
	0 lb. per acre	30 lb. per acre	60 lb. per acre	90 lb. per acre	120 lb. per acre
Beans (4-yr. av.)					
Early and medium, bu.	56	110	166	192	211
Total, bu.	68	140	207	241	270
Lima Beans (4-yr. av.)					
Early and medium, bu.	92	127	155	189	193
Total, bu.	114	143	178	219	227
Beets (2-yr. av.)					
Roots, lb.	750	4,050	5,600	6,150	6,900
Total, lb.	2,338	10,019	12,580	13,476	14,930
Cabbage (4-yr. av.)					
Marketable, lb.	3,200	8,320	12,860	16,840	20,700
Total, lb.	11,000	19,060	26,120	32,360	35,820
Chinese Cabbage (4-yr. av.)					
Total, lb.	7,144	20,641	31,067	40,062	45,459
Carrots (4-yr. av.)					
Marketable, lb.	1,601	6,428	9,668	11,829	14,278
Roots, lb.	2,622	6,137	8,201	9,239	10,307
Total, lb.	5,611	11,918	16,126	18,516	21,314
Chard, Swiss (4-yr. av.)					
Total, lb.	3,982	7,868	7,501	6,554	7,766
Collards (3-yr. av.)					
Total, lb.	7,847	11,920	16,140	16,973	18,556
Corn, sweet (5-yr. av.)					
Marketable, lb.	747	2,095	3,589	5,893	7,216
Total, lb.	1,679	4,610	7,540	9,013	10,261
Eggplant (3-yr. av.)					
Early and medium, lb.	1,277	7,363	12,492	15,152	12,952
Total, lb.	1,833	10,560	16,901	21,667	19,032
Endive (3-yr. av.)					
Total, lb.	1,435	5,501	8,393	10,310	9,805
Kale (4-yr. av.)					
Total, lb.	2,423	5,537	7,413	8,138	9,105
Kohlrabi (3-yr. av.)					
Enlarged stems, lb.	1,485	5,760	10,137	8,637	9,072
Total, lb.	2,207	7,231	11,700	10,771	11,800

(*Continued*)

[1] Amount applied to each of three crops grown each year on same land; 80 pounds of P_2O_5 and 45 pounds of K_2O per acre were added to all treatments.

TABLE 5. (*Continued*) YIELD OF DIFFERENT VEGETABLE CROPS GROWN ON NORFOLK SOIL FROM APPLICATION OF DIFFERENT AMOUNTS OF NITROGEN, FIELD BINS, MAIN STATION, AUBURN, ALABAMA

Crop	Yield per acre on Norfolk soil from different rates of N [1]				
	0 lb. per acre	30 lb. per acre	60 lb. per acre	90 lb. per acre	120 lb. per acre
Lettuce, spring (4-yr. av.)					
Total, lb.	2,789	6,217	6,857	7,319	8,759
Lettuce, fall (3-yr. av.)					
Total, lb.	4,008	6,399	6,852	8,511	8,884
Pepper (2-yr. av.)					
Early and medium, lb.	3,129	10,729	13,139	13,706	15,096
Total, lb.	4,188	14,237	17,462	19,536	23,418
English Peas (4-yr. av.)					
Total, lb.	523	1,783	2,183	2,533	2,525
Potatoes (4-yr. av.)					
Marketable, bu.	66	119	151	184	191
Total, bu.	90	168	207	246	259
Okra (2-yr. av.)					
Early and medium, lb.	1,526	2,521	4,056	3,813	4,180
Total, lb.	2,490	4,290	6,614	6,217	6,585
Onion (4-yr. av.)					
Total, lb.	3,064	5,491	6,503	7,729	7,886
Radish (3-yr. av.)					
Roots, lb.	2,616	4,522	4,777	5,292	5,171
Total, lb.	4,512	7,231	7,502	8,172	8,021
Rutabaga (2-yr. av.)					
Roots, lb.	8,864	20,084	25,524	30,298	30,762
Total, lb.	14,864	31,610	41,556	54,813	60,254
Squash (4-yr. av.)					
Early and medium, lb.	915	6,695	11,176	15,109	16,069
Total, lb.	1,625	8,068	13,466	18,656	18,986
Sweetpotatoes (4-yr. av.)					
Marketable, bu.	165	299	350	380	432
Total, bu.	203	349	412	455	505
New Zealand Spinach (4-yr. av.)					
Total, lb.	6,273	13,178	16,674	20,510	18,320
Tendergreen (3-yr. av.)					
Total, lb.	4,619	13,378	17,269	18,379	18,592
Tomatoes, summer (3-yr. av.)					
Early and medium, lb.	8,158	14,140	15,086	14,180	16,228
Total, lb.	10,221	16,380	18,593	18,326	21,236
Turnip (3-yr. av.)					
Roots, lb.	5,880	11,443	14,250	15,017	14,804
Total, lb.	12,878	25,385	32,899	37,398	38,960

[1] Amount applied to each of three crops grown each year on same land; 80 pounds of P_2O_5 and 45 pounds of K_2O per acre were added to all treatments.

Increases in yield of most crops from increases in nitrogen applications were rather uniform up to the 90-pound rate. Some crops however, gave larger increases from the first 30 pounds applied than from the same increment at higher rates.

The increases in yields of beans (Table 5, page 17) are typical of the responses of most of the crops to the additional increments of nitrogen applied. Without nitrogen the bean yield was 68 bushels. From the first 30-pound increment, the increase was 72 bushels per acre; from the second, 67 bushels; from the third, 34 bushels; and from the fourth, 29 bushels. Assuming a maximum cost of $6.30 for each 30 pounds of nitrogen added and a value of 5 cents per pound for the beans, the increase in yield per $1 of cost from the first increment was worth about $17, from the second $16, from the third about $8, and from the fourth about $7.

Potash Studies on Norfolk and Cecil Soils

The potash studies were conducted on Norfolk sandy loam and Cecil sandy clay soils. The results from 21 crops are given in Table 6.

The rates of potash used were 0, 15, 30, and 45 pounds per acre of K_2O. The cost range of each increment was from $.45 to $.80.

The response of different crops was much less pronounced from applications of potash than from applications of the other two fertilizer elements. Some crops produced about as high yields without potash as with any amount. Other crops, however, gave material increases in yield from potash applications. Beans, lima beans, cabbage, kale, English peas, and tendergreen with no potash produced yields about as high as those from any amount applied. Potash applications on Norfolk soil resulted in yield increases of 24 per cent for rutabagas, 74 per cent for sweetpotatoes, 34 per cent for beets (roots), and 31 per cent for carrots.

An application of 30 pounds per acre of potash increased the yield of No. 1 potatoes on Norfolk soil 47 bushels. Sweetpotatoes produced yield increases of 148 bushels per acre of No. 1's from 45 pounds per acre of potash on Norfolk soil and 92 bushels per acre from 30 pounds of potash on Cecil soil.

It is pointed out that, although the increases in yields are small from applications of potash, the cost of the potash required is so low that the value of the increase may be many times the

TABLE 6. YIELDS OF DIFFERENT VEGETABLE CROPS GROWN ON NORFOLK AND CECIL SOILS FROM APPLICATION OF DIFFERENT AMOUNTS OF POTASH, FIELD BINS, MAIN STATION, AUBURN, ALABAMA

Crop	Yields per acre for different rates of potash (K_2O)							
	Pounds of K_2O per acre applied to Norfolk soil [1]				Pounds of K_2O per acre applied to Cecil soil [1]			
	0	15	30	45	0	15	30	45
Beans (4-yr. av.)								
Early and medium, bu.	187	193	197	193	90	96	96	95
Total, bu.	224	232	234	231	122	131	131	132
Lima Beans (4-yr. av.)								
Early and medium, bu.	176	195	172	186	97	100	106	104
Total, bu.	194	212	193	208	182	179	183	194
Beets (2-yr. av.)								
Roots, lb.	7,450	8,450	9,350	9,950	4,450	5,850	5,300	5,100
Total, lb.	14,731	15,852	17,071	18,071	9,269	11,378	10,696	10,480
Cabbage (4-yr. av.)								
Marketable, lb.	12,680	13,560	13,660	13,580	14,580	15,720	15,040	16,280
Total, lb.	28,560	27,380	27,880	30,400	28,380	28,880	28,880	30,220
Chinese Cabbage (3-yr. av.)								
Total, lb.	23,354	25,654	25,990	25,604	24,056	24,974	27,024	25,996
Carrots (4-yr. av.)								
Marketable, lb.	5,710	7,655	7,597	7,485	5,302	8,533	7,946	9,601
Roots, lb.	5,366	6,524	6,562	6,014	5,849	7,232	7,745	8,427
Total, lb.	11,112	13,297	13,173	12,419	12,617	15,141	16,454	17,008
Chard, Swiss (3-yr. av.)								
Total, lb.	4,281	6,233	8,550	7,886	17,388	25,157	23,520	23,425
Collards (3-yr. av.)								
Total, lb.	12,363	14,562	14,356	12,845	15,016	17,096	16,847	17,396
Endive (2-yr. av.)								
Total, lb.	5,311	8,251	8,606	8,404	7,129	8,573	8,849	8,852
Kale (3-yr. av.)								
Total, lb.	7,523	7,012	6,760	7,198	7,734	9,060	9,013	8,751
English Peas (3-yr. av.)								
Total, lb.	2,489	2,794	2,533	2,281	3,915	4,421	4,344	4,231
Potatoes (4-yr. av.)								
Marketable, bu.	163	190	210	195	139	155	151	148
Total, bu.	220	254	271	256	185	201	195	188

(*Continued*)

[1] Amount of potash applied to each of three crops grown on same land the same year; 80 pounds per acre of P_2O_5 and 90 pounds per acre of N were applied to all treatments.

TABLE 6. (*Continued*) YIELDS OF DIFFERENT VEGETABLE CROPS GROWN ON NORFOLK AND CECIL SOILS FROM APPLICATION OF DIFFERENT AMOUNTS OF POTASH, FIELD BINS, MAIN STATION, AUBURN, ALABAMA

Crop	Yields per acre for different rates of potash (K_2O)							
	Pounds of K_2O per acre applied to Norfolk soil [1]				Pounds of K_2O per acre applied to Cecil soil [1]			
	0	15	30	45	0	15	30	45
Onions (4-yr. av.)								
Total, lb.	7,054	7,553	7,514	7,890	10,288	10,632	10,208	11,200
Radish (2-yr. av.)								
Roots, lb.	4,718	5,069	5,241	4,732	3,678	4,060	4,184	4,012
Total, lb.	7,580	8,605	8,049	7,858	6,425	6,980	7,284	6,894
Rutabaga (2-yr. av.)								
Roots, lb.	23,482	24,973	26,186	29,069	25,130	31,287	28,941	30,134
Total, lb.	45,236	49,937	51,313	56,026	51,114	56,414	55,376	57,364
Squash (2-yr. av.)								
Early and medium, lb.	7,414	10,076	8,782	10,461	4,121	4,433	5,016	4,888
Total, lb.	10,443	12,623	11,088	13,280	5,351	6,190	7,690	6,891
Sweetpotatoes (4-yr. av.)								
Marketable, bu.	245	306	346	393	210	267	302	300
Total, bu.	289	361	417	502	277	322	365	369
N. Z. Spinach (4-yr. av.)								
Total, lb.	6,900	7,616	6,402	8,766	12,005	11,962	15,378	15,951
Tendergreen (2-yr. av.)								
Total, lb.	16,785	17,144	17,862	17,996	12,750	13,260	13,441	11,354
Tomatoes (4-yr. av.)								
Early and medium, lb.	4,984	4,905	4,995	5,700	2,260	4,951	3,572	4,161
Total, lb.	14,205	13,672	12,862	13,714	11,869	15,315	14,744	16,685
Turnips (3-yr. av.)								
Roots, lb.	8,746	8,804	8,654	9,224	5,910	6,686	5,873	6,162
Total, lb.	26,525	26,672	26,331	28,534	17,698	19,421	18,275	19,222

[1] Amount of potash applied to each of three crops grown on same land the same year; 80 pounds per acre of P_2O_5 and 90 pounds per acre of N were applied to all treatments.

cost of the material. For example, there was an increase of 2,199 pounds per acre in the yield of collards on Norfolk soil from an application of 15 pounds per acre of K_2O. At $25 per ton for collards and at the maximum price for potash, the increase would be worth about $35 for $1 expenditure for potash.

Fertilizer Grade Studies with Different Vegetable Crops

Studies of fertilizer grades were conducted both in field bins and in field plots. Some of the experiments were carried on at the Main Station, others at outlying points.

Studies in Field Bins

The three soils used in the field bin studies were Decatur, Hartsells, and Chesterfield. The first two were introduced, while the third was a local soil. The fertilizer treatments used on the Hartsells and Decatur soils were in duplicate, and on the Chesterfield they were in quadruplicate.

Experiments on Decatur Soil. The rates applied to the Decatur soil were as follows: 0, 30, 60, 90, and 120 pounds per acre of N; 0, 40, 80, 120, and 160 pounds per acre of P_2O_5; and 0, 22.5, 45, and 67.5 pounds per acre of K_2O. Results on 12 crops are presented in Table 7.

The cost during the past 20 years for each increment of nitrogen has ranged from about \$2.50 to \$6.30, of phosphorus from \$1.60 to \$2.80, and of potash from \$.68 to \$1.20.

Nitrogen and phosphorus gave pronounced increases in yield of most crops. In general, higher rates of nitrogen were required to reach maximum yields than those of phosphorus. The response of the different crops to applications of potash on the Decatur soil was about the same as that obtained on the Norfolk and Cecil soils as previously described. Potash gave but small increases in yield with most crops on Decatur soil; the exceptions were lettuce, broccoli, tendergreen, and sweetpotatoes.

A few crops might be used to illustrate the effects of the three elements on crop yields. Yields of beans were increased from 118 bushels per acre to 235 bushels as the rates of nitrogen were increased from 0 to 120 pounds per acre. The increases were 45, 39, 11, and 22 bushels per acre for the four successive increments. Yields were increased from 155 to 201 bushels as the rates of P_2O_5 were increased from 0 to 160 pounds per acre. The increases were 22, 9, 12, and 3 bushels per acre for the four successive increments. The yields of this crop from the no-potash treatment were practically as high as those from any rate applied.

Increases in yields of sweetpotatoes were 75, 31, 4, and 45 bushels per acre for the four successive nitrogen increments, 5

TABLE 7. YIELDS OF DIFFERENT VEGETABLE CROPS GROWN ON DECATUR SOIL FROM APPLICATION OF DIFFERENT AMOUNTS OF NITROGEN, PHOSPHORUS, AND POTASH, FIELD BINS, MAIN STATION, AUBURN, ALABAMA

Amount applied per acre [1]	Yields per acre on Decatur soil for different rates of nitrogen, phosphorus and potash											
	Beans (2-yr. av.)		Lima Beans (2-yr. av.)		Beets (2-yr. av.)		Broccoli (2-yr. av.)		Cabbage (4-yr. av.)		Lettuce (2-yr. av.)	
	Early	Total	Early and medium	Total	Roots	Total	Marketable [2]	Total [2]	Heads	Total	Heads	Total
	Lb.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
Nitrogen (N)												
0	82	118	114	141	365	1,636	1,188	7,155	1,498	6,954	269	7,386
30	108	163	141	174	2,741	7,194	1,984	12,381	5,557	12,575	2,951	15,533
60	127	202	126	175	5,622	11,424	3,133	17,098	14,363	20,472	2,522	15,088
90*	125	213	149	193	6,711	14,675	4,202	18,407	22,034	26,706	3,072	17,488
120	139	235	161	193	7,498	16,675	4,528	22,983	26,081	30,258	2,871	15,562
Phosphorus (P_2O_5)												
0	100	155	142	162	1,252	3,674	246	916	1,058	4,655	0	1,402
40	116	177	131	170	6,980	15,360	3,799	17,146	17,583	22,562	346	7,658
80	120	186	142	182	6,861	15,085	4,346	19,424	20,209	24,660	1,709	13,482
120	135	198	137	172	6,138	12,912	4,010	19,824	20,455	26,695	1,626	13,082
160*	129	201	169	214	5,175	11,431	4,426	18,893	17,258	22,666	3,651	15,277
Potash (K_2O)												
0	125	218	162	207	4,101	10,365	3,290	15,587	16,733	22,355	858	7,347
22.5	125	215	170	223	5,466	12,877	3,965	17,930	16,415	21,384	2,250	13,328
45.0	125	213	132	173	5,581	12,761	3,885	17,264	18,740	23,141	2,470	15,565
67.5*	127	224	165	203	7,155	14,361	3,930	21,047	20,594	24,906	3,056	16,362

(*Continued*)

[1] Amount applied to each of two crops grown same year on same area.
Rates of each element applied when other elements were varied are indicated by asterisk (*).
[2] Marketable yield consists of flower parts and total yield consists of whole plant less flower part.

TABLE 7. (*Continued*) YIELDS OF DIFFERENT VEGETABLE CROPS GROWN ON DECATUR SOIL FROM APPLICATION OF DIFFERENT AMOUNTS OF NITROGEN, PHOSPHORUS, AND POTASH, FIELD BINS, MAIN STATION, AUBURN, ALABAMA

Amount applied per acre[1]	Yields per acre on Decatur soil for different rates of nitrogen, phosphorus and potash									
	Onions (4-yr. av.)	Potatoes (4-yr. av.)		Sweetpotatoes Porto Rico (3-yr. av.)		Sweet Corn (2-yr. av.)		Tender-green (4-yr. av.)	Turnips (4-yr. av.)	
	Total	Market-able	Total	Market-able	Total	Market-able	Total	Total	Roots	Total
	Lb.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
Nitrogen (N)										
0	7,162	75	104	241	295	487	1,466	5,243	7,878	15,520
30	9,153	100	131	313	370	3,488	6,087	11,109	10,982	23,427
60	10,876	136	168	327	401	6,842	9,280	15,260	11,681	27,684
90*	12,693	152	183	333	405	7,859	10,848	19,094	12,418	29,991
120	12,720	168	204	348	450	10,269	12,298	20,891	12,934	31,689
Phosphorus (P_2O_5)										
0	5,167	92	118	311	414	3,584	6,144	1,985	1,888	4,838
40	8,272	114	140	347	419	8,103	11,421	18,190	12,687	29,075
80	10,159	129	163	368	459	8,602	11,597	18,553	13,328	30,191
120	11,239	144	178	330	412	9,261	12,301	13,867	13,011	30,855
160*	11,540	161	194	285	411	9,936	11,824	12,102	13,312	31,150
Potash (K_2O)										
0	11,827	147	178	254	338	6,983	11,005	10,815	12,277	29,162
22.5	13,233	164	194	303	362	8,778	11,834	15,174	13,134	31,358
45.0	11,979	166	200	324	376	8,803	11,882	18,131	12,189	29,617
67.5*	11,396	153	184	368	430	8,765	11,194	19,789	11,992	30,930

[1] Amount applied to each of two crops grown same year on same area.
Rates of each element applied when other elements were varied are indicated by asterisk (*).

and 40 bushels for the first two phosphorus increments, and 24, 14, and 54 bushels per acre for the three potash increments.

Highest yields were obtained from 120 pounds per acre of nitrogen applied to beans, beets, broccoli, cabbage, potatoes, sweetpotatoes, sweet corn, tendergreen, and turnips; highest yields of lima beans, lettuce, and onions were obtained from 90 pounds per acre of nitrogen.

Yields of beans, lettuce, and potatoes continued to increase from applications as high as 160 pounds per acre of P_2O_5. Maximum or near-maximum yields of beets were obtained from 40 pounds per acre; of broccoli, onions, turnips, tendergreen, sweetpotatoes, and cabbage from 80 pounds; and of sweet corn from 120 pounds.

Maximum or near-maximum yields were obtained from the following rates: beans, no-potash rate; onions, lima beans, sweet corn, broccoli, and turnips, 22.5 pounds per acre of K_2O; potatoes,

TABLE 8. YIELDS OF DIFFERENT VEGETABLE CROPS GROWN ON HARTSELLS SOIL FROM APPLICATIONS OF DIFFERENT AMOUNTS OF NITROGEN, PHOSPHORUS, AND POTASH, FIELD BINS, MAIN STATION, AUBURN, ALABAMA

Amt. applied per acre [1]	Yields per acre on Hartsells soil for different rates of nitrogen, phosphorus, and potash									
	Beans (3-yr. av.)		Lima Beans (2-yr. av.)		Broccoli (2-yr. av.)		Cabbage (4-yr. av.)		Lettuce (2-yr. av.)	
	Early	Total	Early and med.	Total	Market-able	Total	Heads	Total	Heads	Total
Lb.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
Nitrogen (N)										
0	74	109	101	137	1,293	7,088	630	6,898	80	3,514
30	98	178	122	160	2,394	13,219	8,255	16,044	615	7,335
60	110	202	146	191	3,655	17,747	16,806	23,264	1,495	11,005
90*	120	209	154	184	4,640	21,968	22,228	27,305	3,248	17,709
120	118	222	171	216	5,629	25,050	27,230	31,379	3,744	17,187
Phosphorus (P_2O_5)										
0	76	124	144	176	147	464	627	4,899	0	391
20	80	135	148	182	3,223	12,064	14,092	20,692	0	1,623
40	100	166	152	195	4,182	17,635	18,836	24,566	474	6,029
60	100	174	146	179	4,259	18,778	20,310	26,153	1,252	9,623
80*	96	175	123	176	4,640	18,996	18,477	24,353	1,834	11,671
Potash (K_2O)										
0	111	181	140	179	4,480	17,504	17,308	23,701	256	6,535
22.5	107	179	140	178	4,192	19,507	18,733	25,425	1,287	11,811
45	110	189	153	189	4,522	18,759	24,853	28,954	2,650	15,152
67.5*	108	189	165	199	4,375	19,155	22,465	27,584	1,866	13,850

(*Continued*)

[1] Amount applied to each of two crops grown same year on same area. Rates of each element applied when other elements were varied are indicated by asterisk (*).

TABLE 8. (*Continued*) YIELDS OF DIFFERENT VEGETABLE CROPS GROWN IN HARTSELLS SOIL FROM APPLICATIONS OF DIFFERENT AMOUNTS OF NITROGEN, PHOSPHORUS, AND POTASH, FIELD BINS, MAIN STATION, AUBURN, ALABAMA

Amt. applied per acre[1]	Yields per acre on Hartsells soil for different rates of nitrogen, phosphorus, and potash									
	Onion (4-yr. av.)	Potatoes (4-yr. av.)		Sweet-potatoes Porto Rico (3-yr. av.)		Sweet Corn (2-yr. av.)		Tender-green (4-yr. av.)	Turnips (4-yr. av.)	
	Total	Marketable	Total	Marketable	Total	Marketable	Total	Total	Root	Total
	Lb.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
Nitrogen (N)										
0	5,025	58	81	254	316	0	608	4,237	6,726	11,920
30	8,313	97	131	375	465	3,191	5,741	10,471	12,348	23,745
60	10,371	118	153	447	532	6,147	9,197	15,115	14,699	30,196
90*	13,104	119	165	467	558	8,794	10,736	18,336	14,939	35,066
120	11,826	130	184	441	549	8,666	11,459	20,646	14,245	36,267
Phosphorus (P_2O_5)										
0	3,822	76	115	424	531	3,792	7,027	2,536	4,342	10,797
20	4,941	92	132	409	516	6,650	9,056	14,578	11,956	25,339
40	8,269	112	150	407	523	6,612	9,216	16,955	13,644	31,688
60	8,253	114	155	434	522	6,855	9,242	17,770	14,278	31,774
80*	9,502	118	163	393	535	6,451	9,015	14,313	12,751	30,419
Potash (K_2O)										
0	10,741	116	155	316	408	4,372	8,887	9,368	15,285	31,846
22.5	11,517	113	147	352	421	6,832	9,277	16,538	15,036	34,060
45.0	11,766	119	161	363	472	6,586	9,712	17,723	15,607	35,436
67.5*	10,808	116	158	389	505	7,578	10,582	18,078	15,298	34,761

[1] Amount applied to each of two crops grown same year on same area. Rates of each element applied when other elements were varied are indicated by asterisk (*).

45 pounds; and lettuce, sweetpotatoes, tendergreens, cabbage, and beets, 67.5 pounds.

EXPERIMENTS ON HARTSELLS SOIL. With one exception, the experiments on the Hartsells soil were identical to those on the Decatur soil. The rates of phosphorus used on the lighter Hartsells soil were one-half of those used on the heavier Decatur clay. Yields of 11 crops are given in Table 8.

Responses to the three elements were about the same as those obtained on the other soils. However, responses of most crops on the Hartsells soil were higher from nitrogen applications and lower from phosphorus applications than those obtained on the Decatur clay. Except for lettuce, sweetpotatoes, and tendergreens, responses to potash applications were small.

TABLE 9. YIELDS OF DIFFERENT VEGETABLE CROPS GROWN ON CHESTERFIELD SOIL OF MEDIUM FERTILITY FROM APPLICATIONS OF DIFFERENT FERTILIZER GRADES, FIELD BINS, MAIN STATION, AUBURN, ALABAMA

Fertilizer grade, 1,000 pounds per acre [1]	Yields per acre on Chesterfield soil of medium fertility for different rates of nitrogen, phosphorus, and potash												
	Pole Beans (3-yr. av.)		Sweetpotatoes Porto Rico (2-yr. av.)		Sweetpotatoes Triumph (2-yr. av.)		Sweet Corn (4-yr. av.)		Tender-green (3-yr. av.)	Tomatoes (3-yr. av.)		Turnips (5-yr. av.)	
	Early and med.	Total	Market-able	Total	Market-able	Total	Market-able	Total	Total	Market-able	Total	Roots	Total
N-P-K	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Lb.*	*Lb.*	*Lb.*	*Bu.*	*Bu.*	*Lb.*	*Lb.*
8-10-6	231	365	295	460	253	563	2,305	4,881	15,521	419	585	10,777	27,487
8-10-0	111	212	219	296	183	335	1,371	2,976	12,548	367	509	12,077	25,078
8-10-4	243	391	332	431	256	537	2,679	5,149	15,270	424	550	11,219	28,581
8-10-6	249	402	311	445	274	564	2,633	5,170	14,399	395	547	11,397	29,116
8-10-8	251	399	319	450	301	548	2,584	5,323	15,466	427	553	11,255	28,871
0-10-6	84	191	127	188	222	338	384	1,173	4,415	146	214	4,843	10,262
4-10-6	204	337	281	364	283	523	1,771	4,042	9,911	282	417	9,749	22,896
6-10-6	244	403	315	420	271	583	2,688	5,016	12,982	347	493	11,400	27,756
8-10-6	261	418	332	457	292	541	2,332	4,989	13,727	422	572	11,292	29,262
8-0-6	147	293	278	388	205	411	1,446	3,258	11,754	341	553	9,226	22,512
8-8-6	234	383	300	431	264	560	2,608	5,209	13,483	427	555	10,895	28,085
8-10-6	223	371	314	413	271	514	2,758	5,046	13,336	373	535	10,811	28,274
8-12-6	240	389	312	423	273	551	2,448	5,022	13,400	432	559	10,946	27,847
8-10-6	223	371	314	413	271	514	2,758	5,046	13,336	373	535	10,811	28,274
12-15-9	215	372	325	483	253	563	2,576	5,385	16,720	466	618	11,076	29,502

[1] Amount applied to each of two crops grown each year on same area, with the exception of one crop of sweetpotatoes per year.

TABLE 10. YIELDS OF DIFFERENT VEGETABLE CROPS GROWN ON CHESTERFIELD SOIL OF LOW FERTILITY FROM APPLICATIONS OF DIFFERENT FERTILIZER GRADES, FIELD BINS, MAIN STATION, AUBURN, ALABAMA

Fertilizer grade, 1,000 pounds per acre [1]	Yields per acre on Chesterfield soil of low fertility for different rates of nitrogen, phosphorus, and potash						Fertilizer grade, 1,000 pounds per acre [1]	Yields per acre on Chesterfield soil of low fertility for different rates of nitrogen, phosphorus, and potash				
	Beans (3-yr. av.)		Broccoli (2-yr. av.)	Cabbage (2-yr. av.)		Mustard (2-yr. av.)		Kohlrabi (2-yr. av.)		Onions (2-yr. av.)	Potatoes (2-yr. av.)	
	Early and med.	Total	Total [2]	Marketable	Total	Total		Crown	Total	Total	Marketable	Total
N-P-K	*Bu.*	*Bu.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	N-P-K	*Lb.*	*Lb.*	*Lb.*	*Bu.*	*Bu.*
8-10-0	94	122	7,917	6,243	11,386	4,749	6-10-0	506	3,037	4,106	54	78
8-10-4	115	160	10,858	6,595	14,742	8,067	6-10-4	1,011	4,666	6,138	73	100
8-10-6	123	170	11,264	8,198	16,998	10,061	6-10-6	1,178	4,963	6,291	71	102
8-10-8	137	177	10,855	7,395	15,991	12,032	6-10-8	1,024	4,861	6,279	67	95
0-10-6	19	23	1,332	0	1,981	1,172	0-10-6	35	1,043	1,978	27	39
6-10-6	111	142	8,896	5,562	13,232	8,387	2-10-6	387	2,528	3,878	43	63
10-10-6	146	201	12,746	8,707	18,186	12,135	4-10-6	733	3,664	5,280	58	83
12-10-6	142	199	11,338	9,066	17,991	11,092	8-10-6	1,277	5,392	6,400	85	110
8-0-6	101	138	2,992	4,163	9,590	640	6-0-6	467	2,131	2,746	35	56
8-6-6	130	171	10,250	7,626	14,897	8,490	6-6-6	980	4,585	5,850	70	100
8-8-6	129	171	10,115	6,803	14,941	8,157	6-8-6	1,188	4,371	6,163	68	94
8-12-6	134	181	11,315	8,522	16,656	10,327	6-12-6	1,027	4,714	5,700	76	100
6-6-4	109	142	9,670	5,533	13,472	8,727	4-6-4	605	3,514	5,216	57	79
12-15-9	140	206	10,448	9,543	18,515	11,248	9-15-9	813	4,086	6,215	87	114

[1] Amount applied to each of two crops grown same year on same area.
[2] Broccoli consists of whole plant, no flower parts.

EXPERIMENTS ON CHESTERFIELD SOIL. Experiments were conducted on two Chesterfield soils, one of medium fertility and the other of low fertility. The rates of the three elements in the fertilizer are expressed as grades rather than as pounds of each. The basic application consisted of 1,000 pounds per acre of fertilizer. The rates were 0, 40, 60, and 80 pounds of N; 0, 80, 100, and 120 pounds per acre of P_2O_5; and 0, 40, 60, and 80 pounds per acre of K_2O.

Results of the studies on the better Chesterfield soils are given in Table 9, and those on the poorer soil are presented in Table 10.

Responses of crops to potash on both Chesterfield soils were considerably higher than those obtained on the other soils studied. Increases in yields from 40 pounds per acre of K_2O applied to the better Chesterfield soil were as follows: pole beans from 212 to 391 bushels per acre, sweetpotatoes (Porto Rico variety) from 296 to 431 bushels, sweet corn from 2,976 to 5,149 pounds, and marketable tomatoes from 367 to 424 bushels. Similar responses were obtained on the Chesterfield soil of low fertility.

In general, response to phosphorus applications on both Chesterfield soils were less than those on other soils except on the Hartsells. Response to nitrogen was about the same on the Chesterfield soil of medium fertility as it was on the other soils, but it was much greater on the soil of low fertility than on any of others studied.

Studies in Field Plots

Fertilizer experiments have been conducted in regular field plots at the Main Station, Auburn, three substations, two experiment fields, and at Thorsby and Atmore. Results of a number of these experiments are given in Tables 11 to 19, inclusive.

EXPERIMENTS AT MAIN STATION. Results of fertilizer studies with the Porto Rico variety of sweetpotato on a Norfolk and on a Chesterfield soil and with the Triumph variety on a Chesterfield soil, are reported in Table 11. Rates of nitrogen, phosphorus, and potash are expressed as fertilizer grades. The base application was 1,000 pounds per acre. The rates were 0, 40, 60, 80, and 100 pounds per acre of N; 0, 60, 80, and 100 pounds per acre of P_2O_5; and 0, 40, 60, and 80 pounds per acre of K_2O.

Material increases in yield of both varieties of potatoes on the Chesterfield soil and of the Porto Rico on both soils were obtained from applications of potash and nitrogen. Yield increases were small from applications of phosphorus. Increased yields of

TABLE 11. YIELDS OF SWEETPOTATOES GROWN ON NORFOLK AND CHESTERFIELD SOILS FROM APPLICATIONS OF DIFFERENT FERTILIZER GRADES, FIELD PLOTS, MAIN STATION, AUBURN, ALABAMA

Fertilizer		Yields per acre				
		Chesterfield soil		Norfolk soil		Chesterfield soil
		Porto Rico (3-yr. average)		Porto Rico (2-yr. average)		Triumph (3-yr. av.)
Grades [1]	Amount per acre	Marketable	Total	Marketable	Total	Total
N-P-K	*Lb.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
6-10-0	1,000	134	169	157	188	253
6-10-4	1,000	142	193	178	212	301
6-10-6	1,000	160	208	166	214	325
6-10-8	1,000	166	220	196	235	342
0-10-6	1,000	77	121	104	130	171
4-10-6	1,000	134	189	160	195	297
6-10-6	1,000	168	211	183	223	321
8-10-6	1,000	185	229	191	225	356
10-10-6	1,000	175	219	178	214	355
6-0-6	1,000	169	216	174	215	324
6-6-6	1,000	180	232	174	213	330
6-8-6	1,000	155	200	170	205	319
10-10-6	600	152	193	166	204	306
6-10-6	600	130	188	150	183	257
6-10-6	1,200	168	214	185	222	318
6-10-6	800	142	192	169	209	310

[1] All phosphorus as superphosphate, all potash as muriate of potash, and one-third nitrogen as ammonium sulphate were applied prior to planting; two-thirds of nitrogen as nitrate of soda was applied as side application 3 to 4 weeks after plants were up to stand.

each variety on both soils were obtained from applications up to 80 pounds per acre of potash and of nitrogen.

EXPERIMENTS AT THE GULF COAST SUBSTATION. The crops studied at the Gulf Coast Substation consisted of those of commercial importance in the truck-growing area of the Gulf Coast region. The more important crops studied were grown on freshly cleared land, referred to as "new land," and on land that had been in cultivation for a long period, designated as "old land." Experiments were also conducted on new land after it had been cleared and in cultivation for 5 or more years.

The studies were conducted on Orangeburg and Norfolk sandy loam soils. The Orangeburg soil was old land and the Norfolk was new land.

Fertilizer treatments consisted of different grades and rates of fertilizers. The rates varied with different crops. Results are given in Tables 12 to 14, inclusive.

One of the most pronounced differences among the three elements was in response to phosphorus. With the exception of sweetpotatoes, near failure and in most cases complete failure of crops resulted on new land without the addition of some phosphorus. On old land receiving some phosphorus in previous years, fair yields were obtained without phosphorus.

For example, at the no-phosphorus rate, cabbage yields were 0.26 tons on new land and 10.56 tons per acre on old land (Table 13), while Irish potatoes produced 28 bushels on new land and 109 bushels per acre on old land (Table 14). Sweetpotatoes, however, produced fair yields on new land with no phosphorus added.

Fair yields of all crops were produced on new land without potash. However, applications of potash gave material increases in yields. Pronounced potash deficiencies were observed with some crops where potash was not applied. Cabbage showed typical potash deficiency at the leaf margins. Foliage of Irish potatoes receiving no potash was several shades greener than those receiving some potash.

With most crops, 3 per cent K_2O at the commonly applied rate of application of a complete fertilizer gave near-maximum yields. Exceptions were sweetpotatoes and Irish potatoes, where 6 or 8 per cent was needed.

On new land 24 pounds per acre of K_2O increased the yield of beans from 116 to 151 bushels per acre (Table 12); 36 pounds increased the yield of cucumbers from 94 to 155 bushels per acre; 45 pounds increased the yield of No. 1 potatoes from 68 to 129 bushels; 30 pounds increased the yield of watermelons from 10,642 to 12,227 pounds; 45 pounds increased the yield of head cabbage from 3.13 to 6.61 tons; and 24 pounds increased the yield of roasting corn from 31 to 44 crates per acre.

Although yield increases from potash were low as compared to those from either nitrogen or phosphorus, applications of potash gave high returns. An application of 90 pounds per acre of K_2O resulted in an increased yield of 92 bushels of No. 1 potatoes (Table 12). The value of the increased yield would range from

TABLE 12. YIELDS OF DIFFERENT VEGETABLE CROPS FROM APPLICATIONS OF DIFFERENT FERTILIZER GRADES, FIELD PLOTS, GULF COAST SUBSTATION, FAIRHOPE, ALABAMA

Fertilizer grades [1]	Yields per acre, Norfolk soil, new land [2]					Fertilizer grades [1]	Yields per acre, Norfolk soil, new land [2]			
	Beans [3] (5-yr. av.)	Cucumbers [3] (2-yr. av.)	Potatoes [3] (5-yr. av.)		Watermelons [3] (2-yr. av.)		Cabbage [3] (4-yr. av.)		Roasting Corn [3] (5-yr. av.)	
	Total	Total	No. 1's	Total	Total		Marketable	Total	Marketable	Total
N-P-K	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Lb.*	N-P-K	*Ton*	*Ton*	*Crt.*	*Crt.*
6-10-6	133	124	147	189	12,089	8-10-6	7.01	16.13	40	46
6-10-0	116	94	68	110	10,642	8-10-0	3.13	9.34	31	37
6-10-3	151	155	129	175	12,227	8-10-3	6.61	15.33	44	51
6-10-9	149	145	156	196	12,557	8-10-9	6.89	16.34	49	55
6-10-6	161	163	160	201	12,591	8-10-6	7.37	17.05	44	50
0-10-6	49	66	61	94	8,932	0-10-6	1.21	4.02	6	7
3-10-6	114	143	128	174	11,764	4-10-6	4.47	10.99	33	37
9-10-6	151	127	153	196	11,981	12-10-6	8.68	18.66	43	48
6-10-6	147	140	148	191	13,425	8-10-6	7.83	15.04	41	47
6-0-6	8	1	11	27	.....	8-0-6	0	0	0	0
6-5-6	92	109	122	166	12,648	8-5-6	5.75	13.90	23	27
6-15-6	157	167	160	202	13,850	8-15-6	7.68	16.32	49	56
6-10-6	164	160	150	193	13,618	8-10-6	7.00	15.00	40	47
6-10-6	154	143	150	192	13,502	8-10-6	7.23	16.48	48	54
9-15-9	177	165	179	223	11,841	12-15-9	8.63	19.63	47	58
3-5-3	102	105	99	142	11,754	4-5-3	3.92	10.38	21	25
6-10-6	149	130	147	190	12,351	8-10-6	6.89	15.93	44	50

[1] All phosphorus as superphosphate, all potash as muriate of potash, and one-third of the nitrogen as ammonium sulphate were applied prior to planting; two-thirds of nitrogen as nitrate of soda was applied as side applications 3 to 4 weeks after plants were up to stand.

[2] By "new land" is meant recently cleared land.

[3] Beans and roasting corn were fertilized at rate of 800 pounds per acre, cucumbers at 1,200 pounds, potatoes and cabbage at 1,500 pounds, and watermelons at 1,000 pounds.

TABLE 13. YIELDS OF DIFFERENT VEGETABLE CROPS FROM APPLICATIONS OF DIFFERENT FERTILIZER GRADES, FIELD PLOTS, GULF COAST SUBSTATION, FAIRHOPE, ALABAMA

Fertilizer grades applied at 800 pounds per acre [1]	Yields per acre, Norfolk soil, new land after 5 yr. [2]				Fertilizer grades applied at 1,500 pounds per acre [1]	Yields per acre			
	Beans (4-yr.av.)	Roasting Corn (4-yr.av.)		English Peas (4-yr.av.)		Orangeburg soil old land [2] Cabbage (4-yr.av.)		Norfolk soil — new land after 5 years [2] Cabbage (4-yr.av.)	
	Total	Marketable	Total	Total		Marketable	Total	Marketable	Total
N-P-K	*Bu.*	*Crt.*	*Crt.*	*Lb.*	N-P-K	*Ton*	*Ton*	*Ton*	*Ton*
8-10-6	101	78	92	4,229	10-10-6	9.66	16.23	12.03	21.41
8-10-0	87	37	45	3,382	10-10-0	8.17	16.12	3.66	8.21
8-10-4	105	76	91	4,298	10-10-4	8.45	16.22	11.86	21.41
8-10-8	95	78	96	4,197	10-10-8	7.86	15.75	12.19	20.79
8-10-6	99	79	97	4,354	10-10-6	8.84	16.73	12.45	21.44
0-10-6	19	21	31	1,087	0-10-6	3.59	10.01	7.01	13.27
6-10-6	106	73	82	4,047	8-10-6	8.65	16.37	13.29	26.57
10-10-6	96	81	101	3,903	12-10-6	9.39	16.24	11.69	20.02
8-10-6	102	80	100	4,102	10-10-6	9.23	16.75	12.42	21.48
8-0-6	17	2	5	323	10-0-6	4.76	10.56	0	.26
8-8-6	64	65	81	3,804	10-8-6	8.42	16.13	10.48	18.37
8-12-6	110	77	98	4,487	10-12-6	9.41	15.99	13.67	22.76
8-10-6	107	68	87	4,184	10-10-6	8.38	15.75	11.59	21.13
8-10-6	101	73	93	4,349	10-10-6	7.93	15.84	12.32	21.57
10-12-8	100	76	99	4,353	12-12-8	8.32	15.98	13.03	22.45
6-8-4	105	66	84	3,673	8-8-4	7.03	13.65	10.99	19.19
8-10-6	100	73	95	4,993	10-10-6	7.97	15.03	11.78	20.03

[1] All phosphorus as superphosphate, all potash as muriate of potash, and one-third of nitrogen as ammonium sulphate were applied prior to planting; two-thirds of nitrogen as nitrate of soda was applied as side application 3 to 4 weeks after plants were up to stand.

[2] By "new land after 5 years" means land that has been in cultivation 5 years or more; by "old land" is meant land in cultivation for many years.

TABLE 14. YIELDS OF SWEETPOTATOES AND POTATOES FROM APPLICATIONS OF DIFFERENT FERTILIZER GRADES, FIELD PLOTS, GULF COAST SUBSTATION, FAIRHOPE, ALABAMA

Fertilizer grades applied at 1,200 pounds per acre [1]	Yields per acre Norfolk soil, new land		Fertilizer applied [1]		Yields per acre, Orangeburg soil, old land		Fertilizer grades applied at 1,500 pounds per acre [1]	Yields per acre			
	Triumph sweetpotato early crop 5-year av.		Grades	Rate per acre	Triumph sweetpotato late crop 3-yr. av.	Porto Rico sweetpotato late crop 2-year av.		Orangeburg soil, old land		Norfolk soil new land after 5 years	
								Potatoes, Triumph 5-year av.		Potatoes, Triumph 4-year av.	
	Marketable	Total			Total	Total		No. 1's	Total	No. 1's	Total
N-P-K	*Bu.*	*Bu.*	N-P-K	*Lb.*	*Bu.*	*Bu.*	N-P-K	*Bu.*	*Bu.*	*Bu.*	*Bu.*
6-10-6	170	222	4-10-6	600	400	332	6-10-6	117	155	129	170
6-10-0	97	129	4-10-0	600	199	172	6-10-0	111	152	39	72
6-10-3	157	208	4-10-4	600	384	298	6-10-4	139	180	115	153
6-10-9	177	242	4-10-8	600	489	395	6-10-8	131	171	132	173
6-10-6	171	223	4-10-6	600	468	372	6-10-6	141	182	122	160
0-10-6	133	173	0-10-6	600	414	318	0-10-6	72	109	59	93
3-10-6	148	197	2-10-6	600	466	339	4-10-6	138	178	117	155
9-10-6	173	213	6-10-6	600	452	347	8-10-6	140	180	118	158
6-10-6	187	235	4-10-6	600	421	391	6-10-6	133	175	118	161
6-0-6	70	92	4-0-6	600	264	366	6-0-6	73	109	9	28
6-5-6	174	219	4-8-6	600	425	351	6-8-6	131	177	99	138
6-15-6	186	239	4-12-6	600	408	331	6-12-6	144	186	141	184
6-10-6	173	228	4-10-6	600	451	353	6-10-6	142	183	132	175
6-10-6	190	238	0-0-0	0	357	181	6-10-6	143	185	121	161
9-15-9	185	262	4-10-6	800	484	403	8-12-8	147	187	126	165
3-5-3	164	200	4-10-6	400	409	284	4-8-4	126	168	100	140
6-10-6	193	241	4-10-6	600	420	295	6-10-6	135	177	118	159

[1] All phosphorus as superphosphate, all potash as muriate of potash, and one-third of nitrogen as ammonium sulphate were applied prior to planting; two-thirds of nitrogen as nitrate of soda was applied as side application 3 to 4 weeks after plants were up to stand.

about $140 to $185; the cost of the potash would range from about $3 to $5.

Response of crops to potash was less pronounced on old land that had received some potash than on new land that had received no potash. On old land (Orangeburg), an application of 60 pounds per acre of K_2O increased the yield of cabbage from 8.17 to only 8.45 tons per acre, whereas on new land 60 pounds increased the yield from 3.66 to 11.86 tons. The increased yields of potatoes were from 111 to 139 bushels per acre on old land and from 39 to 115 bushels on new land from 60 pounds per acre of K_2O.

Nitrogen applications markedly affected yields of crops on both new and old land. In most cases 6 per cent nitrogen seemed adequate for most crops at the fertilizer rate used. Maximum or near-maximum yields were obtained on new land from the following nitrogen rates: beans, 48 pounds per acre of N; cucumbers, 36 pounds; potatoes, 90 pounds; watermelons, 60 pounds; cabbage, 180 pounds; early sweetpotatoes, 72 pounds; and roasting corn, 64 pounds.

On new land 5 years after clearing, maximum or near-maximum yields were obtained from 48 pounds per acre of nitrogen applied to beans, 64 pounds to roasting corn, 48 pounds to English peas, 120 pounds to cabbage, and 60 pounds to Irish potatoes.

The nitrogen requirement on old land was not materially different from that on new land. Maximum or near-maximum yields of potatoes and cabbage on old land resulted from 60 and 150 pounds per acre of nitrogen, respectively.

Practically no crop yields were obtained on new land without phophorus with exception of sweetpotatoes. Maximum or near-maximum crop yields were obtained on new land from applications of 80 pounds per acre P_2O_5 for beans, 120 pounds for cucumbers, 150 pounds for potatoes, 100 pounds for watermelons, 225 pounds for cabbage, and 120 pounds for roasting corn. On new land, 5 years after clearing, maximum or near-maximum yields resulted from applications of phosphorus at 80 pounds per acre of P_2O_5 for beans, 96 pounds for roasting corn and for English peas, 180 pounds for cabbage, and 150 for potatoes.

Crop yields were much higher on old land from no-phosphorus treatments than on new land, although about the same amount of phosphorus was required on old as on new land for maximum or near-maximum yields.

TABLE 15. YIELDS OF DIFFERENT VEGETABLE CROPS ON RUSTON SOIL FROM APPLICATIONS OF DIFFERENT FERTILIZER GRADES, FIELD PLOTS, THORSBY, ALABAMA

Fertilizer grades [1]	Yields per acre		
	Beans	Potatoes	
	(4-yr. av.) Total	(4-yr. av.) No. 1's	(4-yr. av.) Total
N-P-K	*Hampers*	*Bushels*	*Bushels*
6-10-6	72	83	113
6-10-0	71	75	109
6-10-3	78	90	121
6-10-9	74	90	124
6-10-6	76	89	123
0-10-6	10	20	36
3-10-6	62	78	110
9-10-6	84	93	121
6-10-6	74	92	126
6-0-6	46	41	61
6-5-6	76	90	122
6-15-6	82	97	131
6-10-6	82	101	134
9-15-9	83	101	129
6-10-6 [2]	77	105	137
6-10-6	72	92	124

[1] Beans were fertilized at rate of 800 pounds per acre, and potatoes at 1,500 pounds per acre.

All superphosphate, muriate of potash, and one-third nitrogen as ammonium sulphate were applied at planting; two-thirds as nitrate of soda was applied 2 to 3 weeks after plants were up to stand.

[2] All nitrogen was derived from ammonium sulphate and was applied before planting.

EXPERIMENTS AT THORSBY. Experiments at Thorsby were conducted cooperatively on a truck grower's farm. The soil was a Ruston of fairly high fertility. Results of fertilizer studies with beans and potatoes are given in Table 15.

Maximum or near-maximum yields of beans were obtained from applications of 24 pounds of K_2O, 72 pounds of N, and 80 pounds of P_2O_5 per acre. For potatoes, applications of 45 pounds of K_2O, 90 pounds of N, and 150 pounds P_2O_5 per acre gave maximum or near-maximum yields.

EXPERIMENTS AT TENNESSEE VALLEY SUBSTATION. Fertilizer studies with a number of vegetable crops were conducted at the Tennessee Valley Substation. The soil is a good grade Decatur

clay. Results from the work with potatoes, sweetpotatoes, and cabbage are given in Table 16.

Applications of 90 pounds K_2O per acre, 60 pounds N, and 150 pounds P_2O_5 gave maximum or near-maximum yields of Irish potatoes. Treatments of 30 pounds of K_2O, 40 pounds of N, and 100 pounds of P_2O_5 resulted in maximum or near-maximum yields of sweetpotatoes; while 72 pounds of K_2O, 108 pounds N, and 120 pounds P_2O_5 gave maximum or near-maximum yields of cabbage.

By increasing the application of 4-10-6 fertilizer from 1,500 to 2,250 pounds (equivalent of 1,500 pounds of 6-15-9) the yield of potatoes was increased from 144 bushels to 170 bushels per acre.

TABLE 16. YIELD OF DIFFERENT VEGETABLE CROPS ON DECATUR SOIL FROM APPLICATIONS OF DIFFERENT FERTILIZER GRADES, FIELD PLOTS, TENNESSEE VALLEY SUBSTATION, BELLE MINA, ALABAMA

Fertilizer grades [1]	Yields per acre		Fertilizer grades applied at 1,200 pounds per acre [1]	Yields per acre
	Potatoes (5-yr av.)	Sweetpotatoes (5-yr av.)		Cabbage (3-yr. av.)
	Total	Total		Total
N-P-K	*Bushels*	*Bushels*	N-P-K	*Tons*
4-10-6	144	333	6-10-6	6.84
4-10-0	131	279	6-10-0	6.30
4-10-3	142	286	6-10-3	6.87
4-10-9	156	293	6-10-9	7.78
4-10-6	149	282	6-10-6	7.99
0-10-6	72	276	0-10-6	3.96
2-10-6	126	285	3-10-6	6.69
6-10-6	156	289	9-10-6	8.61
4-10-6	153	315	6-10-6	6.34
4-0-6	111	272	6-10-6	7.60
4-5-6	138	293	6-0-6	3.03
4-15-6	152	284	6-5-6	6.38
4-10-6	152	305	6-15-6	8.03
4-10-6 [2]	136	307	6-10-6	8.17
4-10-6 [3]	147	310	All manure [4]	5.51
6-15-9	170	315	6-10-6 + Ca [5]	8.19
4-10-6	144	336	9-15-9	8.07

[1] Potatoes were fertilized at the rate of 1,500 pounds per acre and sweetpotatoes at 1,000 pounds. All phosphorus as superphosphate, all potash as muriate of potash, and one-third of nitrogen as ammonium sulphate were applied at time of planting; two-thirds of nitrogen as nitrate of soda was applied after planting.

[2] All nitrogen as cottonseed meal was applied before planting.

[3] One-third of nitrogen as cottonseed meal was applied before planting.

[4] Stable manure was applied at rate of 20 tons per acre.

[5] Lime added.

EXPERIMENTS AT SAND MOUNTAIN SUBSTATION. Studies on the Sand Mountain Substation were conducted on a Hartsells sandy loam soil of fair fertility. Results of fertilizer experiments with sweetpotatoes, potatoes, and cabbage are given in Table 17.

On this soil maximum or near-maximum yields of sweetpotatoes were obtained from applications of 90 pounds of K_2O, 60 pounds of N per acre, and zero phosphorus. Applications of 90 pounds of K_2O, 90 pounds of N, and 150 pounds of P_2O_5 per acre for potatoes resulted in maximum or near maximum yields. Treatments of 72 pounds of K_2O, 108 pounds of N, and 180 pounds of P_2O_5 per acre gave approximately the highest yields of cabbage.

TABLE 17. YIELDS OF DIFFERENT VEGETABLE CROPS ON HARTSELLS SOIL FROM APPLICATIONS OF DIFFERENT FERTILIZER GRADES, FIELD PLOTS, SAND MOUNTAIN SUBSTATION, CROSSVILLE, ALABAMA

Fertilizer grades [1]	Yields per acre				Fertilizer grades applied at 1200 pounds per acre [1]	Yields per acre
	Sweetpotatoes (5-yr. av.)		Potatoes (5-yr. av.)			Cabbage (2-yr. av.)
	No. 1's	Total [2]	No. 1's	Total [2]		Total
N-P-K	*Bu.*	*Bu.*	*Bu.*	*Bu.*	N-P-K	*Tons*
4-10-6	165	220	110	133	6-10-6	8.50
4-10-0	121	167	72	97	6-10-0	6.44
4-10-3	159	214	103	127	6-10-3	7.27
4-10-9	167	231	111	134	6-10-9	7.66
0-10-6	102	149	27	48	6-10-6	6.79
4-10-6	149	200	93	115	0-10-6	1.25
2-10-6	151	201	84	103	3-10-6	5.76
6-10-6	185	236	125	148	9-10-6	8.84
4-0-6	167	224	53	70	6-10-6	8.49
4-5-6	165	223	98	123	6-10-6	7.14
4-10-6	152	201	101	124	6-0-6	.78
4-10-6	133	186	106	131	6-5-6	7.30
4-15-6	151	204	108	132	6-15-6	9.47
4-10-6 [3]	151	207	122	166	6-10-6	9.48
4-10-6 [4]	156	208	118	143	All manure [5]	7.36
6-15-9	191	239	111	135	6-10-6	10.50
4-10-6	150	195	93	116	9-15-9	12.35

[1] Sweetpotatoes were fertilized at the rate of 1,000 pounds per acre and potatoes at 1,500 pounds. All phosphorus as superphosphate, all potash as muriate of potash, and one-third of nitrogen as ammonium sulphate were applied at time of planting; two-thirds of nitrogen as nitrate of soda was applied after planting.

[2] Total includes only No. 1's and No. 2's.

[3] All nitrogen as cottonseed meal was applied before planting.

[4] One-third of nitrogen as cottonseed meal was applied before planting.

[5] Stable manure was applied at rate of 20 tons per acre.

When the application of the 4-10-6 fertilizer was increased from 1,000 pounds to 1,500 pounds per acre (equivalent to 1,000 pounds of 6-15-9), yields of No. 1 sweetpotatoes were increased from 150 to 191 bushels per acre. Similarly, the yield of cabbage was increased from 10.50 to 12.35 tons per acre by increasing the application of 6-10-6 fertilizer from 1,200 to 1,800 pounds per acre (equivalent to 1,200 pounds of 9-15-9).

EXPERIMENTS AT STATE FARM. Fertilizer studies at the State Farm, Atmore, were confined to sweetpotatoes. The soil is a fertile Red Bay sandy loam, which had received liberal applications of fertilizers in previous years. Results are presented in Table 18.

On this well fertilized and productive soil, quite satisfactory yields of the Triumph and the Porto Rico varieties were obtained even when any one of the three elements was omitted. The yield of the Porto Rico variety was not increased by applications of potash although the yield of Triumph was increased somewhat by 40

TABLE 18. YIELDS OF SWEETPOTATOES ON RED BAY SOIL FROM APPLICATIONS OF DIFFERENT FERTILIZER GRADES, FIELD PLOTS, STATE FARM, ATMORE, ALABAMA

Fertilizer		Yields per acre		
Grades [1]	Amount per acre	Porto Rico (3-year average)		Triumph (2-yr. av.)
		Marketable	Total	Total
N-P-K	*Pounds*	*Bushels*	*Bushels*	*Bushels*
6-10-0	1,000	298	402	310
6-10-4	1,000	272	404	338
6-10-6	1,000	299	411	316
6-10-8	1,000	309	429	336
0-10-6	1,000	252	362	317
4-10-6	1,000	303	421	343
6-10-6	1,000	297	424	305
8-10-6	1,000	288	407	358
10-10-6	1,000	272	390	351
6-0-6	1,000	271	399	334
6-6-6	1,000	275	402	345
6-8-6	1,000	290	411	323
10-10-6	600	302	415	306
6-10-6	600	267	369	332
6-10-6	1,200	284	415	337
6-10-6	800	298	408	321
12-10-6	600	282	390	332

[1] All phosphorus as superphosphate, all potash as muriate of potash, and one-third of nitrogen as ammonium sulphate were applied at planting; two-thirds of nitrogen as nitrate of soda was applied as side application.

pounds per acre of K_2O. An application of 40 pounds per acre of N increased the yield of the Porto Rico variety 51 bushels and the yield of the Triumph variety 26 bushels per acre. Applications of phosphorus did not materially increase the yield of either variety.

Increasing the rate of a 6-10-6 fertilizer from 600 to 1,200 pounds per acre increased the yield of the Porto Rico variety from 369 bushels to 415 bushels per acre. The yield of the Triumph variety was not increased by the larger application.

EXPERIMENTS AT BREWTON AND MONROEVILLE EXPERIMENT FIELDS. Fertilizer experiments with sweetpotatoes were conducted on both the Brewton and Monroeville Experiment Fields. The soil at Brewton is a Norfolk sandy loam, while that at Monroeville is an Orangeburg sandy loam soil. Results are presented in Table 19.

TABLE 19. YIELDS OF TRIUMPH SWEETPOTATOES FROM APPLICATIONS OF DIFFERENT FERTILIZER GRADES, FIELD PLOTS, BREWTON AND MONROEVILLE EXPERIMENT FIELDS

Fertilizer		Yields per acre	
Grades [1]	Rate per acre	Brewton Norfolk soil (7-year average) Total	Monroeville Orangeburg soil (7-year average) Total
N-P-K	*Pounds*	*Bushels*	*Bushels*
4-10-6	600	141	276
4-10-0	600	76	244
4-10-4	600	134	279
4-10-8	600	144	291
4-10-6	600	150	291
0-10-6	600	105	214
2-10-6	600	140	268
6-10-6	600	155	276
4-10-6	600	160	264
4-0-6	600	123	266
4-8-6	600	154	280
4-12-6	600	145	278
4-10-6	600	160	275
0-0-0	0	74	178
4-8-6	800	172	284
4-8-6	400	138	251
4-10-6	600	163	276

[1] All fertilizer applied at time of planting.

Yields of sweetpotatoes at Monroeville were about twice as high as those at Brewton. Maximum or near-maximum yields of sweetpotatoes were obtained at Brewton from applications of 36 pounds of K_2O, 24 pounds of N, and 48 pounds of P_2O_5 per acre. An application of 36 pounds per acre of K_2O increased the yield 74 bushels per acre over that of the zero-potash treatment; 24 pounds of N increased the yield 55 bushels over the zero-treatment; and 48 pounds of P_2O_5 increased the yield 31 bushels per acre over the zero-phosphorus treatment.

Unfertilized sweetpotatoes yielded an average of 74 bushels per acre in a 7-year period at the Brewton Field. When 4-8-6 fertilizer was applied at 400-, 600-, and 800-pound rates, sweetpotatoes produced yields of 138, 154, and 172 bushels per acre, respectively.

At Monroeville, maximum or near-maximum yields were obtained from applications of 36 pounds of K_2O, 36 pounds of N, and 48 pounds of P_2O_5 per acre. An application of 36 pounds of K_2O per acre gave a yield increase of 47 bushels per acre; 36 pounds of N resulted in a 62-bushel increase, whereas the increase from phosphorus was 14 bushels.

Miscellaneous Fertilizer Experiments

Two studies were conducted at the Main Station, Auburn, dealing with methods of applying fertilizers and with the effects of manure on the fertilizer requirements of vegetable crops. Studies at the Main Station, and at the Gulf Coast Substation, Fairhope, provide data on effects of residual phosphorus and potash.

Methods of Application of Fertilizers

Experiments to determine value of dividing fertilizer materials and value of a complete fertilizer when used with and without animal manure were conducted on a Chesterfield (loamy-sand) soil of low fertility.

The study included both spring and fall crops. Yields of all crops on this soil were low, especially in the spring. Results of chemical tests made after heavy spring rains showed that most of the nitrogen had been lost.

Three treatments were used, each with and without manure. In one treatment, all fertilizer materials were added 10 days before planting. In a second treatment, one-fourth of the nitrogen plus the full amounts of phosphorus and potash were applied

before planting, the remaining nitrogen being applied in three equal applications at 2-week intervals after the crops were up to a stand. One fourth of the complete fertilizer was added before planting in the third treatment, and the other three-fourths were added in three equal applications at 2-week intervals after stands were established. Results are presented in Table 20.

Without manure, spring crops on the light soil used in the study practically failed when all fertilizer materials were applied before planting. Dividing the nitrogen increased the yield of carrots almost 3 times, increased the yield of beets about 15 times, and the yield of mustard about 3 times. Somewhat further increases were obtained by dividing the complete fertilizer. Manure increased materially the yield of each crop with each method of applying the fertilizer materials. Satisfactory yields of spring crops were not obtained until manure was used and the nitrogen or complete fertilizer was divided into several applications.

Yields were affected less in the fall by dividing the fertilizer materials. Manures, however, doubled the yields of fall crops receiving comparable fertilizer treatments.

TABLE 20. CROP RESPONSE TO DIVIDED APPLICATIONS OF FERTILIZER MATERIALS ON CHESTERFIELD SOIL, FIELD BINS, MAIN STATION, AUBURN, ALABAMA

Methods of fertilizer applications [1]	Manure per acre [2]	Total yields per acre					
		Spring crops			Fall crops		
		Carrots (4-yr. av.)	Beets (4-yr. av.)	Mustard (4-yr. av.)	Tendergreens (4-yr. av.)	Turnips (4-yr. av.)	Radishes (2-yr. av.)
	Tons	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
(1)	0	2,102	43	2,026	10,872	15,384	4,243
(2)	0	6,173	663	6,231	10,594	16,896	6,624
(3)	0	7,675	1,051	7,263	12,067	17,386	8,784
(1)	12	7,416	3,802	3,648	20,712	32,185	12,231
(2)	12	14,588	9,235	12,244	22,449	31,565	11,261
(3)	12	15,984	10,752	12,504	22,179	32,813	11,386

[1] Fertilizer (6-8-4) applied at rate of 1,500 pounds per acre to each of the spring and fall crops:
(1) All fertilizer applied before planting.
(2) All phosphorus and potash, and one-fourth nitrogen applied before planting, and three-fourths nitrogen applied in three equal applications at 2-week intervals after crops were up to stand.
(3) One-fourth of complete fertilizer applied before planting, and three-fourths applied in three equal applications at 2-week intervals after crops were up to stand.

[2] Manure applied in August of each year.

Nitrogen, Phosphorus, and Potash Requirements of Vegetable Crops on Thin Soil Receiving Light Application of Manure

Results of other experiments had shown that satisfactory yields of some crops grown on Chesterfield soil of low fertility were not produced irrespective of the amounts of commercial fertilizer used. However, the addition of a small amount of manure resulted in a satisfactory yield. To determine how nitrogen, phosphorus, and potash requirements of crops were affected by manure, an experiment was conducted on this soil.

From 1938 to 1944 regular commercial fertilizer studies were conducted in which no manure was added. Beginning in 1945, stable manure at the rate of 6 tons per acre was included in all treatments.

Prior to 1947, two-thirds of the nitrogen and all of the phosphorus and potash were applied under the crops before planting; the remaining one-third of nitrogen being applied 3 to 4 weeks after the crop was up to a stand. Beginning in 1947, one-half of the P_2O_5 and K_2O and one-third of the N were applied before planting and a similar amount applied as a side application after planting; the remaining one-third of the nitrogen was applied as a second side application.

In this experiment, Irish potatoes, beets, and carrots were grown as spring crops, and turnips and kohlrabi as fall crops. Yields of the five vegetable crops from different rates of nitrogen, phosphorus, and potash are given in Table 21.

From the data it may be observed that, in general, the yield of each crop was much higher after the manure was applied than before. Seasonal conditions and different methods of applying the complete fertilizer, in all probability, played some part in causing these differences. Quantitative comparisons, therefore, of yields before and after applying manure are not warranted. Yields, however, ranged from about 50 to 400 per cent higher after the manure was applied than before. This was true regardless of the method used in applying the complete fertilizer.

The 6 tons of manure apparently provided sufficient amounts of potash for maximum or near-maximum yields. Increases in yield from different rates of potash applications averaged about 39 per cent without manure and about 11 per cent with manure. With most crops the greatest increases in yields were from the first increment of potash.

TABLE 21. FERTILIZER GRADES STUDIES ON POOR SANDY SOILS WITH AND WITHOUT MANURE, FIELD BINS, MAIN STATION, AUBURN, ALABAMA

Treatment		Total yields per acre										
		Potatoes		Beets		Carrots		Kohlrabi		Turnips		
		Manure [2]		Manure [2]		Manure [2]		Manure [2]		Manure [2]		
No.	1,000 pounds per acre [1]	None, 2 crops 1940-43	6 tons, 1 crop 1946	None, 1 crop 1939	6 tons, 1 crop 1948	None, 2 crops 1941-44	6 tons, 1 crop 1947	None, 2 crops 1939-42	6 tons, 1 crop 1945	None, 1 crop 1943	6 tons, 1 crop 1946	6 tons, 1 crop [1] 1948
	N-P-K	*Bushels*	*Bushels*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1	6-10-0	78	135	2,137	7,610	3,601	14,611	3,037	7,610	4,416	18,822	28,454
2	6-10-4	100	130	3,750	6,174	4,516	15,994	4,666	8,787	6,259	22,016	29,107
3	6-10-6	102	140	3,270	8,294	4,327	17,696	4,963	8,518	4,531	23,117	30,867
4	6-10-8	95	133	3,545	7,213	4,128	15,827	4,861	8,858	6,163	24,563	30,573
5	0-10-6	39	107	358	3,488	2,365	7,386	1,043	2,995	3,226	8,864	7,168
6	2-10-6	63	118	1,760	5,645	3,757	11,635	2,528	4,954	2,035	12,403	16,218
7	4-10-6	83	123	3,014	7,782	3,927	14,650	3,664	6,823	3,648	19,558	23,962
8	8-10-6	110	146	5,318	8,096	4,326	19,469	5,392	8,934	5,952	25,850	31,610
9	6-0-6	56	103	2,503	7,277	2,883	12,794	2,131	7,264	1,670	17,754	28,685
10	6-6-6	100	133	4,102	7,821	4,307	17,850	4,585	8,839	3,264	23,213	31,200
11	6-8-6	94	134	4,269	7,616	5,092	17,536	4,371	8,678	5,126	21,523	31,270
12	6-12-6	100	129	3,456	7,283	3,975	18,131	4,714	9,452	4,070	23,317	30,790
13	4-6-4	79	133	3,123	6,592	3,907	14,368	3,514	8,063	3,898	19,834	25,306
14	9-15-9	114	140	4,339	8,845	3,905	18,784	4,086	8,281	7,776	29,600	33,747

[1] Beginning in 1947, the complete fertilizer was divided, one-half P_2O_5 and K_2O, and one-third of nitrogen being applied under the crop two weeks prior to planting and similar amounts applied 3 to 4 weeks after planting; the remaining one-third of nitrogen was applied as a second side application. Before 1947, all P_2O_5 and K_2O, and two-thirds of the nitrogen were applied before planting; one-third of the nitrogen was applied as a side application.

[2] Manure was applied first in 1945.

With three exceptions, increased yields of all crops resulted from each additional increment of nitrogen — from lowest to highest applications. This was true of yields from treatments with or without manure. While relative increases from nitrogen without manure were somewhat larger than those from nitrogen plus manure, the actual increases were higher when manure was included.

The relative increases in yields of the several crops resulting from adding 60 pounds per acre of P_2O_5 over the no-phosphorus application ranged from approximately 50 to 120 per cent without manure, and from approximately 8 to 30 per cent with manure. For most crops, the 100-pound rate of P_2O_5 was adequate irrespective of application of manure.

Residual Effects of Fertilizer Materials

Fertilizer materials may exert a considerable influence on crops following those to which the materials were applied. This is an important point in fertilizing truck crops grown on the same land for many years. The residual effects of nitrogen, phosphorus, and potash differ greatly. The form in which the element is applied, especially of nitrogen, likewise influences residual effects. The residual effects of phosphorus and potash are more pronounced than those of nitrogen.

Midgley *(12)*, Scarseth, and Tidmore *(14, 15)* have shown that large quantities of phosphorus are fixed in the soil. Other investigators *(2, 3, 8)* have shown that plants may utilize much of this fixed phosphorus at later periods. A companion report to this bulletin *(21)* presents considerable evidence on the accumulation of phosphorus in soil and its later availability to plants. An earlier report presented data on the residual effects of phosphorus on yields of Irish potatoes at the Gulf Coast Substation *(19)*.

Data in Tables 13 and 14 give some evidence on residual effects of phosphorus. Sweetpotatoes on new ground (Table 14) produced a total of 92 bushels per acre without phosphorus and 219 bushels from 60 pounds per acre of P_2O_5. On old land that had received phosphorus applications in past years, sweetpotatoes produced 366 bushels per acre without phosphorus and 353 bushels from 60 pounds per acre of P_2O_5. Cabbage, (Table 13) on land that had received no phosphorus, produced 0.26 ton per acre without phosphorus and 21.13 tons from 150 pounds per acre of P_2O_5. On old land previously receiving phosphorus, the yield was 10.56

tons per acre without phosphorus and 15.75 tons from 150 pounds of P_2O_5. Irish potatoes (Table 14) on new ground yielded 28 bushels per acre from no-phosphorus treatment, and 175 bushels from 150 pounds per acre of P_2O_5. On old land without phosphorus, the yield was 109 bushels; and from 150 pounds of P_2O_5, it was 183 bushels per acre.

Residual effects of potash also continue for many years (Tables 13 and 14). The yield of cabbage on land that had received no potash was increased from 8.21 to 21.41 tons per acre by an application of 60 pounds per acre of K_2O. On old land previously fertilized, the yield was 16.12 tons per acre from the no-potash treatment and 16.22 tons on the plot receiving 60 pounds per acre of K_2O. Potatoes (Table 14) on new ground produced only 72 bushels without potash, and 160 bushels from 90 pounds per acre of K_2O. On old land, however, the yield was 152 bushels per acre without potash and 180 bushels from 60-pound application of K_2O.

Residual effects of nitrogen are limited and of short duration. At the Main Station, Auburn, on a light Chesterfield soil, yields were increased in the spring from 2 to 15 times by dividing the application even to a single crop (Table 20).

SUMMARY

Results of fertilizer experiments with vegetable crops at the Main Station, Auburn, and at seven outlying points in the State are reported in this bulletin. Nine soil types and 27 different crops were involved in the study. The studies were confined to rates of nitrogen, phosphorus, and potash and to different rates and grades of fertilizers.

A major portion of the work was done at the Main Station in field bins filled with soils shipped in from several agricultural sections of the State. A few of the experiments at the Main Station and all of those at outlying points were conducted in field plots.

Only one crop was grown each year in field plots; either two or three successive crops were grown in field bins.

In all experiments certain rates of nitrogen, phosphorus, and potash considered adequate to measure the requirements of each crop or group of crops were established. The full amounts of nitrogen were applied to each crop. Where two successive crops were grown on the same land within a year, one-half of the full amounts of phosphorus and potash was applied to each crop; and where 3 successive crops were grown, one-third was applied. The choice of this method of application, based on earlier experiments, proved to be fortunate.

On soils that had received no fertilizers or low applications in past years, phosphorus limited production more completely than did the other two elements. Nitrogen was second, while potash seemed adequate in most soils to give 80 per cent of maximum yields without an application.

Small applications of phosphorus and potash more quickly satisfied requirements of vegetable crops for maximum or near-maximum production than did nitrogen.

Crops were found to differ greatly in their phosphorus requirements and in the amounts required to give maximum or near-maximum yields on different soils.

Vegetable crops as a group on most soils continued to give increased yields from increased applications of nitrogen up to 120 pounds per acre. Yields, however, were generally 90 per cent or more of the maximum when 90 pounds per acre of N was added.

Considered as a group, vegetable crops responded to potash only to a limited extent. In general, soils apparently supplied

enough potash to give 80 to 90 per cent of a maximum yield without the addition of K_2O. Some crops on some soils gave about as high yield without potash as with potash additions. Most crops, however, gave increases from potash additions that justified the cost several times.

Most crops on most soils gave increased yields from applications of nitrogen, phosphorus, and potash worth many times the cost of the materials applied. Even small increases in yields returned several times the cost of the material.

Dividing the nitrogen into several applications increased several times the yield of spring-grown vegetables on light, sandy-type soil.

Phosphorus and potash applications affected the yield of crops for many years, whereas nitrogen effects were of short duration, especially on light soils.

At the Gulf Coast Substation on newly cleared land that had never been fertilized, complete or nearly complete failure resulted when no phosphorus was added with all crops except sweetpotatoes. On the other hand, old land fertilized only moderately for several years produced fair yields on no-phosphorus plots. Response to potash on the new land was relatively low in comparison with responses to phosphorus and nitrogen.

On land at the State Farm, Atmore, that had been heavily fertilized in recent years, high yields were obtained without the application of either phosphorus, nitrogen, or potash.

Response to the three elements at other points in the State varied according to the crop, soil, and past fertilizer treatment. In general, the largest response to applications were obtained from nitrogen, second largest from phosphorus, and third from potash.

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