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# TEXAS AGRICULTURAL EXPERIMENT STATION

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COLLEGE STATION, BRAZOS COUNTY, TEXAS

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DIVISION OF HORTICULTURE

## FERTILIZER EXPERIMENTS WITH YELLOW BERMUDA ONIONS IN THE WINTER GARDEN REGION OF TEXAS



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AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS

T. O. WALTON, President

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Phosphoric acid had the most effect on yields, nitrogen was the next most effective, and potash had practically no effect in four years of fertilizer experiments with Yellow Bermuda onions on Webb fine sandy loam soil at the Winter Garden Station. After the first year, potash sometimes decreases yields rather than increasing them. The use of 600 to 900 pounds per acre of a 6-12-0 fertilizer or a fertilizer which furnishes the nutrients in equivalent amounts and proportions is in general suggested. An amount as large as 1200 pounds, and a fertilizer containing potash, may prove profitable on previously unfertilized land the first year, but is not likely to be profitable thereafter. In the light of the findings reported herein every situation requires individual consideration.

While ammonium sulphate applied alone is not likely to prove very profitable (and in fact may decrease yields on previously unfertilized land), 20 per cent superphosphate used alone at the rate of 360 pounds per acre will normally increase yields to a profitable extent. The two materials combined to make an application equivalent to 600 pounds of 6-12-0 fertilizer were usually more effective in increasing yields than the superphosphate by itself.

The experiments indicate that the application of all the fertilizer to the soil previous to the setting out of the onion plants is the most desirable practice. Sodium nitrate or ammonium sulphate applied as a side dressing is very likely to decrease yields instead of increase them, except in the case of previously unfertilized onions which may respond with slight increases in yield.

The value of several nitrogen carriers including cottonseed meal is reported.

Normally onions receiving 600 to 900 pounds of a 6-12-0 or similar fertilizer will be earlier and also have a higher percentage of U. S. No. 1 bulbs than onions fertilized with other grades.

Whenever larger amounts of nitrogen than those recommended are applied, the harvested onions are likely to decay quicker in common storage than they will if less nitrogen has been applied.

The ill effects due to the damage by thrips (*Thrips tabaci*) can be overcome to a great extent by proper fertilizer practices. A severe attack of the pink root disease (*Fusarium malli*) apparently cannot be combated profitably by applications as large as 1800 pounds per acre of 6-12-6 fertilizer, nor by ordinary fertilizers having other formulas.

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## FERTILIZER EXPERIMENTS WITH YELLOW BERMUDA ONIONS IN THE WINTER GARDEN REGION OF TEXAS

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The culture of Bermuda onions is an important industry in Texas. In 1932, the last year for which published car-lot shipments are available, 28,055 cars of onions were shipped in the United States, 8,342 of which originated in Texas (13)\*. This was a greater number than originated in any other state. Practically all of these cars from Texas were Bermuda onions. In 1926 Texas was credited with raising annually 80 per cent or more of the Bermuda onions in the United States (11). Texas has not always shipped more onions than any other state, but for a number of years the acreage and the car-lot shipments have been high. A large proportion of the onions raised in Texas are grown under irrigation on various sandy loam soils in the Winter Garden area of Southwest Texas (4, 8).

Because the culture under such a system is rather intensive, the cost of growing such a crop is considerably higher than it is with many other vegetables. With such a system it becomes essential that the crop be produced efficiently and economically; otherwise in a year of low prices for the harvested product the losses are likely to be heavy.

The studies reported in this bulletin were carried out at the Winter Garden Substation No. 19 for the purpose of determining as accurately as possible the fertilizer needs of Bermuda onions. Since by far the greater acreage of Bermuda onions is devoted to the Yellow Bermuda variety (4, 11), this was the variety used throughout these experiments. It was planned to find answers to such questions as these: What formula should the fertilizer have? How much of it should be applied? When and how should it be applied? Are side dressings profitable? If so, what kind of side dressings? When should they be applied? Are some fertilizer materials more desirable than others? Does it pay to use fertilizer even in a year of low prices? These and other questions if satisfactorily answered might well lead to a more efficient production of onions at a lower cost per bushel.

### REVIEW OF SOME PREVIOUS WORK

Investigations looking toward better fertilizer practices with onions were carried out on a limited scale from 1904 to 1908 at the Beeville Substation (14). Results of these experiments conducted on a Goliad fine sandy loam indicated that neither nitrogen, phosphoric acid, nor potash applied alone or in combination could be used profitably, as yields from all these treatments were lower than those from the non-fertilized plats. Barnyard manure at the rate of 20 tons per acre resulted in yields higher than those produced on the non-fertilized plats, but the increase in yield was not striking. Cottonseed meal applied alone

\* This and similar numbers refer to references under "Literature Cited."

produced the lowest yield of all treatments. None of these results can be considered very reliable in the light of present experimental methods, since only single plats of each treatment were used.

Fertilizer experiments from 1926 to 1930 on a sandy loam soil in Virginia indicated that of the three nutrients, nitrogen, phosphoric acid, and potash, phosphoric acid was the most essential (12). "The fertilizers from which phosphorus was omitted gave the lowest yields each year. . ." Nitrogen also seemed necessary for good growth since yields were increased as the percentage of ammonia was increased from 0 to 6 per cent in a formula in which the phosphoric acid and the potash were each held constant at 8 per cent. Potash had but little effect on yield. In contrast to this, very decided increases in yield have been obtained in Michigan and New York from increased amounts of potash (3, 6). The experiments in those states, however, were on muck soils deficient in potash. In recent studies in the Connecticut Valley of Massachusetts where the N-P-K ratio was varied on a fine sandy loam, the "greatest response was obtained from an increase of phosphorus, but significant increases were obtained only when potassium was increased also" (1). The most desirable application was 2500 pounds per acre of a 4-12-8 mixture. Raising the percentage of nitrogen from 4 to 6 failed to produce any significant increases in yield when all the fertilizer was applied before sowing the seed (the crop was seeded directly in the field), but when nitrogen was applied later as a side dressing, beneficial increases in yield were obtained. Onions grown from dried sets, however, did not respond to nitrogen side dressings.

In experiments conducted at the New Mexico Agricultural Experiment Station with the new Early Grano onion, superphosphate alone at 220 pounds per acre resulted in the lowest yields in comparison with treatments of ammonium sulphate alone, ammonium sulphate and superphosphate in combination, a complete fertilizer, barnyard manure, and no fertilizer at all (10). The highest yields were from the plats receiving the complete fertilizer. In a storage test connected with these same experiments there was a slight tendency for the onions taken from the heavier yielding plats to show a greater shrinkage in storage, although evidently no significant differences were established.

### METHODS EMPLOYED

**Formulas and Amounts Used:** In order to obtain information of a fundamental nature the first experiments to be carried out in the season of 1931-32 were planned to determine the relative value of nitrogen, phosphoric acid, and potash, and the ratio in which they should be present in a fertilizer mixture.

For this study a 6-12-6 fertilizer made up from 20% sulphate of ammonia, 20% superphosphate, and 48% or 50% muriate of potash applied at a rate equivalent to 600 pounds per acre was used as the basic treatment. This amount and kind of fertilizer is commonly applied by commercial growers. In order to test the value of the individual

nutrients separately, the percentage of each was varied in a series of treatments in which the percentages of the two nutrients not being tested were kept constant. (See table 2a). In this manner the effect of each nutrient could be determined separately without any undue limitations because of lack of the others. This system of testing also enabled a number of formulas with different ratios to be studied. Various amounts ranging from 0 to 1800 lbs. per acre of the complete fertilizer (6-12-6) were also tried. (Table 7a). These experiments were conducted for four seasons ending in 1934-35. Each plat received the same treatment every year.

In 1932 another series of treatments was laid out to supplement and check still further some of the results obtained in the fundamental series initiated in 1931. Ammonium sulphate was tried alone at rates of 180, 360, and 540 pounds per acre, which was equivalent to applying 600, 1200, and 1800 pounds of 6-0-0 fertilizer per acre. Similarly 20 per cent superphosphate was tested alone at rates of 360, 720, and 1080 pounds per acre, which was equivalent to applying 600, 1200, and 1800 pounds of 0-12-0 fertilizer per acre. Both nutrients were then applied together in amounts equivalent to 600, 1200, and 1800 pounds of 6-12-0. With these were compared similar rates of 6-12-6. (Table 3).

Sources of nitrogen were also tried. In this test, nitrate of soda, sulphate of ammonia, cyanamid, and cottonseed meal were all applied at rates to supply 36 pounds of nitrogen per acre. Each was combined with superphosphate to give 72 pounds of phosphoric acid per acre, and with muriate of potash to give 36 pounds of potash per acre. These applications were each equivalent to 600 pounds of 6-12-6 fertilizer per acre.

In addition the two materials having formulas of 11-48-0 and 16-20-0 were also tried at rates to give 36 pounds of nitrogen per acre. Since the formulas of these materials were already fixed, no attempt was made to create a 6-12-6 fertilizer out of them, and hence although they supplied exactly the same amount of nitrogen as 600 pounds of 6-12-6 the amounts of phosphoric acid were different. The 11-48-0 fertilizer gave 157.08 pounds of phosphoric acid per acre, and the 16-20-0 fertilizer supplied 65.45 pounds. All of the treatments testing the source of nitrogen are listed in Table 4. These additional experiments, started in the fall of 1932, were conducted through three seasons ending in 1934-35.

In 1933-34 and 1934-35 an application of 510 pounds per acre of cottonseed meal alone was tried. This was broadcast and harrowed in a week before the onion plants were set out.

**Side Dressings:** During the seasons 1932-33 to 1934-35 various tests were carried out to determine the value of side dressings, since some growers depend entirely on side dressings of nitrate of soda, and others who make an initial application of a complete fertilizer frequently supplement this later with one or more side dressings of sodium nitrate.

Treatments were therefore devised to determine the value of side dressings on onions receiving no fertilizer at time of planting, as well as on onions fertilized at that time. In addition the attempt was also made

to discover if it is profitable to apply a total amount of complete fertilizer as great as 1200 pounds all at one time, or if it is more desirable to split it into an initial application and one or more later applications in the form of side dressings. Besides these side dressings of complete fertilizer three other materials were used as side dressings: nitrate of soda, ammonium sulphate, and ammonium phosphate (11-48-0). The amounts of these materials were adjusted so that the quantity of nitrogen applied by each was equivalent to the amount of that material contained in 100 pounds of ammonium sulphate. The ammonium sulphate, the ammonium phosphate, and half of the sodium nitrate were applied around the middle of January each year, and the remaining half of the sodium nitrate was applied about a month later. Some of the treatments were fertilized before planting with 600 pounds of a 6-12-6 fertilizer; others were not. The exact treatments are listed in Table 8. The side dressings were scattered between the rows by hand and cultivated in, and the plats were irrigated.

**Size and Arrangement of Plats:** The plats in the fundamental series, started in 1931, consisted of eight rows fifty feet long and 14 inches apart. The outer row on each side of the plat was used as a guard row and was not included in the recorded yield of the plat. Likewise an area one foot wide across each end of the plat was not recorded. The area on which data were based was a trifle larger than  $1/130$  of an acre. Each plat was separated from those on either side of it by a three-foot raised border. A similar border extended across the lower end of each plat. These borders not only separated the fertilizer treatments but prevented the movement of irrigation water from one plat to another. The various tiers of plats were irrigated with water coming directly from the reservoir. Drainage ditches were placed to catch any water which broke over or through the lower border of a plat, so that none of it ever reached a supply ditch.

Because the land used for this experiment was terraced and of an irregular shape, the plats could not be arranged in regular straight lines and in large blocks but had to be grouped for the most part in small blocks. The treatments were arranged in the order given in Tables 2a and 7a and were replicated four times.

As it was found that a plat only 50 feet long with a border across the lower end to stop the flow of water did not always "wet up" well, without an opening in the lower end to allow the water to run through a longer time, plats in all the experiments laid out after the first season were made twice as long; that is, 98 feet. The recordable area remained exactly the same, as the yields were based on three rows instead of six.

The plats used for the nitrogenous side dressings, as well as the treatment calling for cottonseed meal alone, were the only ones laid out in new locations each season.

The land used for all of these experiments was a Webb fine sandy loam. It was cleared of native brush in 1930, and some of it had been planted to snap beans and later to field corn before being measured off for the



onion experiments in the fall of 1931. In Table 1 chemical analyses of the soils by the Division of Chemistry are given. These analyses give

**Table 1. Analyses of the soils used**

Nutrient	Fundamental series		Supplementary series	
	Surface soil 0 - 7 in	Subsoil 7 - 19 in	Surface soil 0 - 7 in	Subsoil 7 - 19 in
Nitrogen.....	0.33%	0.27%	0.031%	0.035%
Active phosphoric acid.....	21 ppm	9 ppm	28 ppm	9.5 ppm
Total phosphoric acid.....	0.023%	0.022%	0.022%	0.023%
Active potash.....	200 ppm	185 ppm	200 ppm	223 ppm
Total potash.....	0.54%	0.54%	0.60%	0.60%
Acid consumed.....	3.0%	2.0%	2.0%	3.0%
pH.....	6.43	6.66	6.60	7.13

the composition before the application of any fertilizers or before any crop of onions had been grown. They indicate an abundance of potash but a low supply of nitrogen and phosphoric acid.

**Culture:** In all experiments in which the fertilizer was applied before planting, the material was broadcast by hand. Following this the ridges on which the onion plants were later set out were made. The shovels of the cultivator in making the furrows and in throwing the earth into ridges mixed the fertilizer rather thoroughly throughout the ridge. Broadcasting the fertilizer preceded the setting out by only a day or two. All the planting was done by hand, in the regular commercial way, help especially adept at this operation being employed. Plants were spaced about 3½ inches apart and all spacing in the rows was equal, since the same marking machine was used in all the experiments.

Slight variations in procedure occurred in some seasons, but in any one season all treatments were handled alike. In 1933-34, sulphate of potash was used instead of muriate of potash but tests with onions in Massachusetts have failed to indicate that any significant differences in yield is likely to result from these two sources of potash (1). In 1933-34 and 1934-35, the tops of the onions were not clipped back as is the usual custom, and as they had been in the first two seasons.

Aside from the variations in method made necessary by the technique of the experiment, and by the treatments themselves, the cultural methods followed throughout all the tests were similar to those generally practiced in the Winter Garden area.

**Onion Storage:** An attempt was made in 1931-32 and again in 1932-33 to see whether the various fertilizer treatments of the "fundamental" series had any effect on the keeping quality of onions in common storage. As each plat in this series was harvested, a random sample of 30 to 35 onions from the U. S. No. 1 grade was taken and set aside. In all there were 72 samples, one from each plat. Within a few days or a week these were regraded and reduced in each case to 25 good onions free from decay. All samples, still in paper bags, were then placed in com-

mon storage. In 1931-32 they were stored on a shelf under the tile roof of an open implement shed. In 1932-33 they were placed on the dry concrete floor of a ventilated room in a hollow tile barn. The tops of the bags were left open. Periodically they were examined (see dates in Tables 10 and 11) and the decayed bulbs were counted and removed. In October when there was an increasing tendency for the remaining bulbs to begin sprouting, the test was concluded.

#### EFFECTS OF PINK ROOT, THRIPS, AND FREEZES

During the course of these fertilizer experiments, various factors beyond control affected the results of certain treatments. Since a knowledge of these uncontrolled factors aids in a better understanding of the results produced by the various fertilizers, consideration is given to them here before the detailed discussion of the results is given.

**Freezing injuries:** In the season 1932-33, a severe freeze occurred in early February. This has been fully described in connection with its effect on 20 varieties of onions (7). A temperature as low as 18 degrees F. and a strong continuous wind severely injured the tops of all onions. Many onions were completely killed, and at harvest time a large proportion were classed as splits and doubles (Table 9). This increased the proportion of culls, undoubtedly at the expense of the No. 1 onions. Plats which received little or no fertilizer, or fertilizer lacking an essential nutrient, lost more plants than well-fertilized plats. On the other hand well-fertilized plats, while losing very few plants, had a reduced yield of U. S. No. 1 onions because of the large numbers of splits and doubles.

In the 1934-35 season a similar freeze occurred in late January, when the temperature dropped to 19 degrees F. For some reason, possibly the lack of wind when the temperature was at its lowest, the onions were not injured as severely as they were in 1932-33.

**Pink root and thrips:** In the third season (1933-34), pink root due to *Fusarium malli* was noticeable here and there throughout the fundamental series. It did not, however, affect yields to any measurable extent. In the following season (1934-35), pink root was very serious in this series, affecting almost every plat. As can be seen in Tables 2a and 7a, yields were very much reduced that year and not one of the treatments made profitable yields.

*Thrips tabaci* was very severe in both 1933-34 and 1934-35 but it is believed that the ill effects of thrips can be more easily overcome than those of pink root. The main supplementary series had pink root to some extent in 1934-35 and in general had lower yields that year (Tables 3 and 4). Outside of these two important series none of the other experiments described herein, nor those as yet unreported, suffered from pink root, chiefly because they have been rotated with other crops. However, in spite of suffering just as seriously from the thrips, all treatments yielded very heavily in comparison with those of 1934-35 in the

fundamental series in which there was severe pink root infection. A comparison of almost any of the tables with Tables 2a and 7a illustrates this point.

## EFFECT OF NITROGEN ON YIELD OF ONIONS

### Varying the Proportion of Nitrogen in a Complete Fertilizer

A study of the results obtained during four years from the treatments in which the amount of nitrogen applied was varied while the phosphoric acid and potash were kept constant, indicates that in general nitrogen is beneficial when contained in fertilizers used in onion culture (Tables 2a and 2b). Increasing the amount of nitrogen has not had as marked an effect as increasing the phosphoric acid, nor has the effect been as sustained throughout the four years. In 1931-32 the yield of U. S. No. 1 onions from the 9-12-6 fertilizer treatment was 156 per cent greater than that from the 0-12-6 fertilizer, but three years later (in 1933-34) it was only 16 per cent greater, the same as the 6-12-6 fertilizer, and but one per cent more than the yield produced by 3-12-6. In 1934-35, marked increases in percentage similar to those obtained in 1931-32 were again obtained, but this can be attributed to the low yields throughout, a condition which accentuates the percentage. For the four years of the experiment the 9-12-6 fertilizer made an average yield of 179 bushels of U. S. No. 1 onions per acre as compared with a yield of 128 bushels of U. S. No. 1 onions for the 0-12-6 fertilizer (Table 2a). When total yields are considered, the 9-12-6 fertilizer averaged 274 bushels against 209 for the 0-12-6.

While there was a noticeable tendency throughout the four years of observations for the yields to increase as the amount of nitrogen was increased from 0 to 9 per cent in the formula, a careful analysis of the figures obtained indicates that each added increment of nitrogen did not produce in itself a significant increase in yield. In other words, while the difference in yield between the 0-12-6 and the 9-12-6 fertilizer treatments was usually significant, the differences in yield between 0-12-6 and 3-12-6, or between 3-12-6 and 6-12-6, etc., were frequently not so, although the yields always tended to be higher with the greater amount of nitrogen. The differences became less as the seasons went by until in the third season (1933-34) the yields produced by the 3-12-6, 6-12-6, and 9-12-6 fertilizer treatments were all practically the same. The results indicate that while some nitrogen is beneficial, a high proportion of it in the fertilizer mixture is not profitable year after year.

### Nitrogen Applied Alone

In the experiment just described each of the three nutrients had been varied in quantity in the presence of constant amounts of the other two. As increasing the nitrogen produced marked increases in yield, the purpose of a supplementary test was to determine if a nitrogenous fertilizer by itself has any value. Ammonium sulphate was used as the carrier.

**Table 2a. The effect of varying the ratios of nitrogen, phosphoric acid, and potash on the bushels of onions per acre**

Fertilizer used	U. S. No. 1					Total yield				
	1932*	1933	1934	1935	Aver.	1932	1933	1934	1935	Aver.
No fertilizer.....	59	186	119	6	93	153	242	203	50	162
<b>Nitrogen series:</b>										
0-12-6.....	66	258	182	7	128	170	353	266	48	209
3-12-6.....	116	302	209	14	160	244	386	301	68	250
6-12-6.....	142	280	212	15	162	251	389	299	69	252
9-12-6.....	169	318	211	18	179	286	436	300	73	274
<b>Phosphoric acid series:</b>										
6-0-6.....	40	156	98	4	75	128	202	190	36	139
6-6-6.....	90	251	172	13	132	200	315	258	71	211
6-12-6.....	169	261	192	21	161	253	384	284	78	250
6-18-6.....	198	294	201	16	177	299	450	288	74	278
<b>Potash series:</b>										
6-12-0.....	132	284	236	19	168	255	438	339	75	277
6-12-3.....	161	304	210	14	172	276	376	301	60	253
6-12-6.....	137	291	195	13	159	247	387	281	68	246
6-12-9.....	164	267	234	22	172	308	374	335	85	276

\* This and other years given are the years in which harvest occurred.

**Table 2b. Percentages of increase or decrease in yield of onions due to varying the ratios of nitrogen, phosphoric acid, and potash in the formula**

Fertilizer used	U. S. No. 1					Total yield				
	1932*	1933	1934	1935	Aver.	1932	1933	1934	1935	Aver.
<b>Nitrogen series:</b>										
0-12-6, check.....	—	—	—	—	—	—	—	—	—	—
3-12-6.....	76	17	15	100	25	44	9	13	42	20
6-12-6.....	115	9	16	114	27	48	10	12	44	21
9-12-6.....	156	28	16	157	40	68	24	13	52	31
<b>Phosphoric acid series:</b>										
6-0-6, check.....	—	—	—	—	—	—	—	—	—	—
6-6-6.....	125	61	76	225	76	56	56	36	97	52
6-12-6.....	323	67	96	425	115	98	90	49	117	80
6-18-6.....	395	88	105	300	156	134	123	52	106	100
<b>Potash series:</b>										
6-12-0, check.....	—	—	—	—	—	—	—	—	—	—
6-12-3.....	22	7	-11	-26	2	8	-14	-11	-20	-9
6-12-6.....	4	2	-17	-32	-5	-3	-12	-17	-9	-11
6-12-9.....	24	-6	-1	16	2	21	-15	-1	13	0

\* This and other years given are the years in which harvest occurred.

This material is sometimes used in just this way by commercial growers. The plats receiving 540 pounds of ammonium sulphate (equivalent to 1800 pounds of 6-0-0) made an average yield equivalent to 90 bushels of U. S. No. 1 onions per acre for the three years of the experiment as compared with a yield of 124 bushels of U. S. No. 1 onions for the 180 pounds of ammonium sulphate equivalent to 600 pounds of 6-0-0 (Table 3). The average total yield of onions resulting from the application of 540 pounds of ammonium sulphate was 152 bushels per acre, as compared with an average total yield of 205 bushels from the 180 pounds of ammonium sulphate. In each of the three years, the lowest amount of ammonium sulphate gave as high a yield as any of the ammonium sulphate applications, no significantly higher yields resulting from either

of the other treatments. In the first year of this test (1932-33) all applications of ammonium sulphate resulted in lower yields than were obtained from the no-fertilizer treatment. In 1933-34 and 1934-35 significantly higher yields resulted from the application of the lowest amount of ammonium sulphate, viz. 180 pounds per acre. Evidently ammonium sulphate used alone is not only less effective, but in large applications is even harmful, reducing yields of onions instead of increasing them. This result is much in contrast with that obtained when ammonium sulphate was used as an ingredient of the 3-12-6, 6-12-6, and 9-12-6 fertilizers.

### Sources of Nitrogen

The results from the treatments in this test have varied somewhat from year to year. This indicates that as soil and climatic conditions vary from year to year the response of the crop may also vary. The fertilizers themselves may influence soil conditions from one year to the next, because they often leave residues.

**Nitrate of Soda:** In the first season (1932-33) the 6-12-6 fertilizer containing nitrate of soda resulted in a yield of 282 bushels of U. S. No. 1 onions per acre (Table 4). It was the highest yield in this particular test that year (there were 146 bushels of U. S. No. 1 onions from the unfertilized treatment). In the following season the nitrate of soda treatment failed to produce as well in comparison with the other nitrogen carriers. While it was exceeded in yield by most of them, the sodium nitrate treatment was not significantly lower. In the third season it resulted in next to the highest yield of U. S. No. 1 onions. In general it seems to be a fairly satisfactory carrier of nitrogen. When used by itself its results may not be so good. (See results reported under "Side Dressings.")

**Sulphate of Ammonia:** The mixture containing ammonium sulphate, which was standard in all these tests, resulted in the third highest yield (255 bushels of U. S. No. 1 onions) in the first season. The following season the U. S. No. 1 yield from this treatment was the highest, although it exceeded some others by an insignificant margin (Table 4). In the third year the yield was lower than those from most of the treatments. Sulphate of ammonia has in general given satisfactory results. Theoretically it should in the long run be more beneficial in alkaline soils than sodium nitrate, as its residue is acid, that of nitrate of soda being alkaline. Like sodium nitrate it may not be so beneficial when used alone. (See earlier discussion under "Nitrogen Applied Alone," as well as the report of "Side Dressings" later.)

**Cyanamid:** In two out of three seasons the use of this material in the 6-12-6 mixture resulted in the lowest yields of U. S. No. 1 onions, with the exception of the no-fertilizer treatment (Table 4). In the other season (1933-34) it placed fourth with a yield of 194 bushels, as compared with 207 for ammonium sulphate (highest), and 93 for the unfertilized treatment (lowest).

**Table 3. Effect of various applications of nitrogen and phosphoric acid, alone and in combination, as well as with potash, on the yield of onions (bu. per acre)**

Fertilizer used	U. S. No. 1				Total yields			
	1933	1934	1935	Aver.	1933	1934	1935	Aver.
No fertilizer (check).....	146	93	37	92	208	172	106	162
<b>Nitrogen alone:</b>								
180 lbs. of ammonium sulphate.....	138	175	60	124	172	308	136	205
360 lbs. of ammonium sulphate.....	139	148	63	117	195	231	134	187
540 lbs. of ammonium sulphate.....	83	143	43	90	115	227	113	152
<b>Phosphoric acid alone:</b>								
360 lbs. of 20% Superphosphate....	211	194	64	156	279	306	131	239
720 lbs. of 20% Superphosphate....	191	199	76	155	298	320	148	255
1080 lbs. of 20% Superphosphate....	237	208	75	173	321	310	143	258
<b>Nitrogen and phosphoric acid in combination:</b>								
600 lbs. of 6-12-0.....	211	207	112	177	294	333	184	270
600 lbs. of 6-12-6.....	231	187	103	174	310	289	178	259
1200 lbs. of 6-12-0.....	207	189	105	167	327	301	176	268
1200 lbs. of 6-12-6.....	223	214	91	176	335	316	166	272
1800 lbs. of 6-12-0.....	149	168	88	135	257	254	164	225
1800 lbs. of 6-12-6.....	213	170	79	154	342	277	135	251

**11-48-0 Fertilizer:** The yields obtained from treatments receiving the 11-48-0 fertilizer (ammonium phosphate) have in comparison with the yields from most other treatments been increasingly satisfactory each year. In the second season the yield of 206 bushels of U. S. No. 1 onions from this treatment was for all practical purposes the same as the highest yield (207 bushels) from the ammonium sulphate treatment (Table 4). In the third season the 11-48-0 treatment resulted in the highest yield (86 bushels), although this was not significantly greater than several others. A probable explanation of the success of this fertilizer lies in its high phosphoric acid content.

**16-20-0 Fertilizer:** This material did not prove as satisfactory the first season, resulting in a yield of only 209 bushels of U. S. No. 1 onions, as compared with 282 bushels (highest) from the sodium nitrate treatment. In the following two seasons it resulted in yields which were only very slightly below the highest yield. For all practical purposes they were about the same.

**Cottonseed Meal:** Although this material used in a 6-12-6 fertilizer resulted in the lowest yield (unfertilized plats excepted) in the second season, its effect on yield in the first and last seasons was far from unsatisfactory, and even in the second season the yield was very far from being a failure when compared with the unfertilized treatment (Table 4). In Table 5 yields are given for the harvests of 1934 and 1935 for onions receiving the cottonseed meal alone. This was in a separate series from those just described above, and hence the records for the unfertilized plats, as well as for those receiving the standard 600 pounds of 6-12-6 fertilizer, differ from those given in Table 4. When cottonseed meal is applied alone (a fairly common practice in years when it is cheap), yields are shown to be not very much greater than when no fertilizer at

**Table 4. The effect of the source of nitrogen on yield per acre. (All fertilizers were applied to give 36 lbs. of nitrogen per acre)**

Nitrogen carrier used	Cost of Entire Fertilizer*	U. S. No. 1 (bu.)				Total yield (bu.)			
		1933	1934	1935	Aver.	1933	1934	1935	Aver.
No fertilizer.....	0.00	146	93	37	92	208	172	106	162
Nitrate of soda in 6-12-6.....	11.62	282	191	84	186	376	279	149	268
Sulphate of ammonia in 6-12-6.....	11.11	255	207	74	179	317	305	137	253
Cyanamid in 6-12-6.....	9.76	203	194	68	155	277	277	133	229
Cottonseed meal in 6-12-6.....	13.18	266	181	80	176	329	267	148	248
11-48-0 327½ lbs. per acre.....	11.08	248	206	86	180	361	316	150	276
16-20-0 225 lbs. per acre.....	6.53	209	202	82	164	264	300	154	239

\*Based on average selling prices as given in Texas Agr. Exp. Sta. Bul. 498, Commercial Fertilizers in 1933-34, p. 9.

**Table 5. Effect of cottonseed meal in comparison with no fertilizer and 600 lbs. of 6-12-6 fertilizer on the bushels of onions per acre**

Fertilizer used	U. S. No. 1			Total		
	1934	1935	Aver.	1934	1935	Aver.
No fertilizer.....	90	46	68	156	101	129
510 lbs. of cottonseed meal.....	112	49	81	177	132	155
600 lbs. 6-12-6.....	235	103	169	318	181	250

all is applied. Compared with those from the 600 pounds of 6-12-6 fertilizer, they are extremely low.

**Cost of Various Nitrogen Sources:** The most costly treatment does not necessarily result in the greatest yield (Table 4). Some treatments, too, may be more profitable in one year than they are in others. In 1932-33 the 16-20-0 fertilizer resulted in a return hardly as profitable as those produced from most other treatments. In the two following seasons, however, this material, as has been pointed out, resulted in yields practically equivalent to the highest ones. Figured at the average prices reported for the State of Texas in 1933-34 (2) the 16-20-0 fertilizer cost only \$6.53 an acre, more than \$4.50 less than the 11-48-0 fertilizer, as well as the one in which sulphate of ammonia was used. It cost almost \$5.20 less than the fertilizer containing nitrate of soda. Assuming the response obtained in these two seasons represents normal yields, in those years the 225 pounds of 16-20-0 was the best investment among the various possibilities offered by the treatments in the source of nitrogen test. Because of the low ratio of phosphoric acid to nitrogen in the 16-20-0 fertilizer, it probably would not be as desirable to apply the first year on previously unfertilized land, for reasons which will be discussed later.

**EFFECT OF PHOSPHORIC ACID ON THE YIELD OF ONIONS**

**Varying the Proportion of Phosphoric Acid in a Complete Fertilizer**

Of the three nutrients—nitrogen, phosphoric acid, and potash—phosphoric acid has consistently produced the most marked increase of yield in all four years, and wherever it has been omitted from the fertilizer

the yields have always been the lowest of all treatments, no-fertilizer included (Table 2a). These results resemble rather strikingly those reported from Virginia in 1930 (12).

The 6-18-6 fertilizer resulted in an average yield of 177 bushels of U. S. No. 1 per acre for the four years of test, as compared with a yield of 75 bushels of U. S. No. 1 onions from the 6-0-6 treatment (Table 2a). Average total yields for the four years are in similar proportions, that from the 6-18-6 fertilizer being 278 bushels and that from the 6-0-6 fertilizer 139 bushels. In 1931-32 the yield of U. S. No. 1's from the 6-18-6 was 395 per cent higher than that from the 6-0-6, while in 1933-34 it was down to 205 per cent (Table 2b). This was still a considerable percentage of increase as compared with the nitrogen series. In 1934-35 all yields in this series were seriously reduced by the pink root disease mentioned above, and percentages of increase were hence much accentuated. In that season the increased yield of U. S. No. 1's from an application of 6-18-6 fertilizer was 300 per cent greater than the yield from the 6-0-6 mixture.

The increases in yield which can be attributed to each added increment of phosphoric acid as the formula has been stepped up from 6-0-6 to 6-6-6, to 6-12-6, to 6-18-6, have been markedly more significant than those in the nitrogen series. The greatest difference, with one exception, has always been between the 6-0-6 and the 6-6-6 treatments. Adding a relatively small amount of phosphoric acid to a soil which is apparently very deficient in it produces striking results. As the years have passed, the differences between the 6-12-6 and the 6-18-6 treatments have lessened until in 1934-35 the plats receiving the 6-12-6 fertilizer yielded heavier than those receiving the 6-18-6 mixture (Tables 2a and 2b).

#### Phosphoric Acid Applied Alone

Unlike the nitrogen carrier ammonium sulphate, the phosphoric acid carrier superphosphate increased yields when used alone, in all the three years. Yields did not increase with every increase of the fertilizer material to the extent that they did when the ratios varied all the way from 6-0-6 to 6-18-6 in the fundamental series. Thus 1080 pounds of superphosphate (equivalent to 1800 pounds of 0-12-0) made an average yield of 173 bushels of U. S. No. 1 onions per acre for the three years of the test as compared with 156 bushels of U. S. No. 1 onions resulting from 360 pounds of superphosphate, equivalent to 600 pounds of 0-12-0 per acre (Table 3). There was no significant difference in yield between the applications of 360 pounds and 720 pounds per acre. Under commercial conditions the additional yield obtained from the 1080 pounds per acre would be rather expensive. A comparison of the no-fertilizer treatment and the 360 pounds per acre application of superphosphate indicates that superphosphate applied alone at this rate would be profitable. The average yield for three years from the no-fertilizer plats was 92 bushels of U. S. No. 1 onions, and that from the 360 pounds of superphosphate was 156 bushels of U. S. No. 1 onions.



## EFFECT OF POTASH ON THE YIELD OF ONIONS

### Varying the Proportion of Potash in a Complete Fertilizer

Applications of potash have sometimes increased onion yields, and sometimes decreased them, and in general there has been very little correlation between the result produced by one formula and that produced by another. Omitting potash has never resulted in as low yields as have been obtained by omitting nitrogen and phosphoric acid separately, nor has the addition of potash ever resulted in as marked an increase in yield as can be attributed to the addition of either nitrogen or phosphoric acid (Table 2a and 2b). In 1931-32 the highest yield of U. S. No. 1 onions in the potash series came from the plats receiving the 6-12-9 fertilizer, and the lowest came from those receiving the 6-12-0. However, plats receiving 6-12-3 that year had yields almost as great as those receiving 6-12-9, while the 6-12-6 plats had yields almost as low as those from the 6-12-3 plats. In 1932-33 in the same series, the potash treatment with highest yield of U. S. No. 1 was 6-12-3, and the one with lowest yield was 6-12-9. In 1933-34 the plats receiving no potash had the highest yield, while the plats receiving 6-12-6 had the lowest. The 6-12-9 plats had an even smaller yield than those receiving no potash at all.

A statistical analysis of these results indicates they have very little significance one way or another. This conclusion is supported further by results obtained in the supplementary series first laid out in 1932. In that series potash likewise increased the yield of both U. S. No. 1 onions and the total yield in the first year of both series, and has decreased it in most cases in succeeding years (Table 3).

### Fertilizers with Potash Omitted

In the first year of these fertilizer experiments the only application omitting potash was the one in which 600 pounds of 6-12-0 fertilizer was applied. The supplementary tests begun in 1932 included 1200 and 1800 pounds as well as 600 pounds of 6-12-0 fertilizer.

In the average of the three years the application of 600 pounds of 6-12-0 fertilizer made just as high a yield of U. S. No. 1 onions as did any other treatment including those containing potash (Table 3). This yield of 177 bushels was considerably higher than the yield of 135 bushels obtained from the 1800 pounds of 6-12-0 and slightly higher than the yield of 167 bushels from the 1200 pounds of 6-12-0. It would seem that while applications of nitrogen and phosphoric acid together in such a formula as 6-12-0 are usually more profitable than applications containing potash as well, such as 6-12-6, very large applications are not likely to be profitable.

## RELATIVE EFFECT OF THE DIFFERENT NUTRIENTS

Under the discussion of phosphoric acid it has already been pointed out that yields were reduced more by the omission of that nutrient than

by any other. However, additions of both nitrogen and phosphoric acid increased yields. The comparative effectiveness of all the nutrients is shown in a more condensed form in Table 6.

All unfertilized plats yielded considerably less than those receiving 600 pounds of a 6-12-6 fertilizer. All treatments lacking phosphoric

**Table 6. Comparative effectiveness of the various nutrients**

Treatment	Yield of U. S. No. 1 (bu.)			Total yield (bu.)		
	1st year 1931-32	3rd year 1933-34	Average of 4 years	1st year 1931-32	3rd year 1933-34	Average of 4 years
No fertilizer.....	59	119	93	153	203	162
0-12-6 (600 lbs.).....	66	182	128	170	266	209
6- 0-6 (600 lbs.).....	40	98	75	128	190	139
6-12-0 (600 lbs.).....	132	236	168	255	339	277
6-12-6 (600 lbs.).....	149*	200*	161*	250*	288*	249*

\*An average of the three sets of 6-12-6 plats.

acid resulted in yields less than those obtained without fertilizer, indicating the serious deficiency of available phosphoric acid in the Webb fine sandy loam as regards the need of the onions for this nutrient. This result also indicates that the applications of nitrogen and potash without phosphoric acid would be a very wasteful and unproductive practice. It would add the expense of applying this unbalanced fertilizer, and yet the yields might be less than if no fertilizer had been applied. Where phosphoric acid was present, but no nitrogen included, all yields were still below those obtained from the 6-12-6 fertilizer. This indicates that while both nitrogen and phosphoric acid are effective separately, they are more effective when applied together. Only in the first year was potash at all effective in increasing yield.

On the basis of the soil analyses given in Table 1 these results might be expected. The low amounts of nitrogen and phosphoric acid shown there explain the responses to these nutrients when they are added. The lack of response to additions of potash is consistent with the large amount of that nutrient shown in the analyses.

#### RATES OF APPLICATION OF COMPLETE FERTILIZER (6-12-6)

On the basis of a four-year average, 1800 pounds of 6-12-6 resulted in a yield of 220 bushels of U. S. No. 1 as compared with 93 bushels of U. S. No. 1 from the no-fertilizer plats (Table 7a). The difference in yield between these two treatments has less significance when the results of the individual years are studied separately. In 1931-32 there were 320 bushels of U. S. No. 1 onions per acre from the 1800 pounds of 6-12-6, as compared with only 59 bushels where no fertilizer was applied. With every increase in the amount of fertilizer that year, there was a corresponding increase in both U. S. No. 1 onions as well as in the total

**Table 7a. Effect of various amounts of complete fertilizer (6-12-6) on the bushels of onions per acre**

Pounds of complete fertilizer (6-12-6)	U. S. No. 1					Total yield				
	1932	1933	1934	1935	Aver.	1932	1933	1934	1935	Aver.
No fertilizer.....	59	186	119	6	93	153	242	203	50	162
300 lbs.....	100	343	149	17	152	190	417	232	73	228
600 lbs.....	140	357	205	16	180	240	464	281	76	265
900 lbs.....	219	281	230	20	188	317	441	339	79	294
1200 lbs.....	288	295	215	20	205	367	454	303	79	301
1800 lbs.....	320	297	246	16	220	381	524	340	72	329

**Table 7b. Effects of various amounts of complete fertilizer (6-12-6) on the percentage increase or decrease in yield over or below the check**

Pounds of complete fertilizer (6-12-6)	U. S. No. 1					Total yield				
	1932	1933	1934	1935	Aver.	1932	1933	1934	1935	Aver.
None (check).....	—	—	—	—	—	—	—	—	—	—
300.....	69	84	25	183	63	24	72	14	46	41
600.....	137	92	72	167	94	57	92	38	52	64
900.....	271	51	93	233	102	107	82	67	58	81
1200.....	388	59	81	233	120	140	88	49	58	86
1800.....	442	60	107	167	137	149	117	67	44	103
None.....	-58	-48	-42	-62	-48	-36	-48	-28	-34	-39
300.....	-29	-4	-27	6	-16	-21	-10	-17	-4	-14
600 (check).....	—	—	—	—	—	—	—	—	—	—
900.....	56	-21	12	25	4	32	-5	21	4	11
1200.....	106	-17	5	25	14	53	-2	8	4	14
1800.....	129	-17	20	0	22	59	13	21	-5	24

yield. The U. S. No. 1 yield that year from the 1800 pound plats averaged 442 per cent greater than that from the no-fertilizer treatment (Table 7b). These remarkable increases in yield with increased amounts of complete fertilizer have never been obtained since. With the exception of the plats receiving no phosphoric acid, the no-fertilizer treatment has always had the lowest yield of U. S. No. 1 onions and the lowest total yield, but since the first year, amounts higher than 900 pounds per acre have not always produced higher yields. Sometimes yields have declined with amounts of 6-12-6 fertilizer greater than 900 pounds.

If one is accustomed to using about 600 pounds of 6-12-6 or its equivalent per acre, and hence wishes to consider that amount as the check, then it will be found that with the exception of 1932-33 (year of severe freeze) 900 pounds has always given a yield of U. S. No. 1 onions at least 12 per cent higher than that from the 600 pounds of fertilizer.

Comparable treatments in the supplemental series begun in 1932 produced results which support those just discussed, in spite of the fact that the freeze in February 1933 was a factor in the first year of that series which had been absent in the first year of the fundamental series the year before (Table 3). Quality as expressed in U. S. No. 1 onions was reduced by this freeze, and total yields were also slightly reduced through

loss in stands, and delay in maturity. Hence the increases in yields of U. S. No. 1 onions with every increase of complete fertilizer did not occur in the first year of the supplemental series as it did in the first year of the fundamental series. However, total yields responded in a similar way in both series. The decreasing effect of the larger amounts of fertilizer as the years have gone by is also evident in both series.

## TIME AND METHODS OF APPLICATION OF FERTILIZER

### Time of Application of Complete Fertilizer (6-12-6)

In 1931-32 the 1200 pound rate of 6-12-6 produced a noticeably higher yield than did 900 pounds per acre (Tables 2a and 2b). A question arose. If this continued to be a profitable application, then should the entire 1200 pounds of 6-12-6 be applied all at one time, and if not, when should it be applied? As can be seen from the treatments listed in Table 8, three were tried. The average yields for the three years indicate that applying the entire amount to the soil just before the young onion plants are set out is the best practice. An application of 1200 pounds of 6-12-6 fertilizer broadcasted previous to transplanting made

**Table 8. Effect of time and method of application of complete fertilizer, as well as side-dressings on the yield of onions (bu. per acre)**

Fertilizer used	U. S. No. 1				Total			
	1933	1934	1935	Aver.	1933	1934	1935	Aver.
<b>Applications of complete fertilizer (6-12-6):</b>								
Initial application 1200 lbs. ....	278	223	107	203	397	347	183	309
Initial application 900 lbs. + s. d. 300 lbs. ....	287	223	95	202	425	332	159	305
Initial application 600 lbs. + 2 s. d. 300 lbs. each. ....	274	201	105	193	350	314	190	285
<b>Nitrogenous side-dressings:<sup>4</sup></b>								
600 lbs. of 6-12-6 with no side-dressings later. ....	—	235	103	169	—	318	181	250
600 lbs. of 6-12-6 plus ammonium sulphate <sup>1</sup> side-dressing. ....	—	213	86	150	—	294	157	226
600 lbs. of 6-12-6 plus sodium nitrate <sup>2</sup> side-dressing. ....	—	156	104	130	—	226	178	202
No fertilizer. ....	—	90	46	68	—	156	101	129
No fertilizer initially, but sodium nitrate side-dressing later <sup>2</sup> . ....	—	103	48	76	—	174	121	148
No fertilizer initially but 11-48-0 <sup>3</sup> side-dressing later. ....	—	143	65	104	—	217	138	177

<sup>1</sup>—At rate of 100 lbs. per acre. Applied in January.

<sup>2</sup>—In two equal side-dressings totaling 133 lbs. per acre (equivalent to 100 lbs. of ammonium sulphate). Applied in January and February.

<sup>3</sup>—At a rate of 181.8 lbs. per acre (to give same amount of N as 100 lbs. of ammonium sulphate). Applied in January.

<sup>4</sup>—Yields from these treatments should **not** be directly compared with the three above as they were not in the same fields.

an average yield of 203 bushels of U. S. No. 1 onions or a total yield of 309 bushels, as compared with a yield of 193 bushels of U. S. No. 1 onions or a total yield of 285 bushels for the treatment in which 600 pounds of 6-12-6 fertilizer was broadcasted initially, and the remaining 600 pounds (making 1200 pounds of 6-12-6 in all) applied in two side dress-

ings—one in January, the other in February. On the average of three years, the treatment in which 900 pounds was broadcasted initially and the remaining 300 pounds put on as a side dressing in January, almost equalled the high yielding treatment. Statistically the yields were not significantly less.

Even had the yields from all treatments been alike, the conclusion that the initial application of the entire amount is the best practice would still be correct. Applying the fertilizer at that time is easier, and it eliminates entirely the labor and time consumed in making side dressings later.

### Side Dressings

**Side Dressings to previously fertilized plats:** The plats receiving 600 pounds of 6-12-6 fertilizer made an average yield of 169 bushels per acre of U. S. No. 1 onions and a total yield of 250 bushels for the two years that this experiment has been under way (Table 8). The no-fertilizer treatment in this same series averaged 68 bushels of U. S. No. 1 onions and a total of 129 bushels for the same period. In contrast with these results, the plats receiving 600 pounds of 6-12-6 fertilizer, plus 100 pounds of ammonium sulphate as a side dressing in January, averaged 150 bushels of U. S. No. 1 onions per acre and 226 bushels total. The treatment in which nitrate of soda was substituted for ammonium sulphate averaged 130 bushels of U. S. No. 1 onions and 202 bushels total. In other words, the extra nitrogen either in the form of ammonium sulphate or as nitrate of soda decreased the yields normally resulting from 600 pounds of 6-12-6 fertilizer alone. For some reason the ammonium sulphate gave higher yields the first year than did the sodium nitrate, but the second year it gave lower yields than the sodium nitrate did in either year. The plats receiving ammonium sulphate as a side dressing yielded considerably less than did the plats where it had not been applied at all. Nitrate of soda decreased the yield only in the first year, but although it did not do so the second year, it failed to increase it, and hence was an unprofitable application. The reversal in performance of the ammonium sulphate and nitrate of soda side dressings in 1934-35 corresponded to the treatments in which these had been applied initially as part of a complete fertilizer (Table 4). In 1933-34 the 6-12-6 fertilizer containing ammonium sulphate yielded more than the 6-12-6 fertilizer containing nitrate of soda. In 1934-35 the reverse was true.

The results of the side dressing experiments described above would indicate that applications of either sodium nitrate or ammonium sulphate are likely to be unprofitable in the side dressing of onions which have already received complete fertilizer.

**Side Dressings Without Previous Fertilization:** Sodium nitrate applied to previously unfertilized plats at the same rate as in the side dressings discussed above made an average yield of 76 bushels of U. S. No. 1 onions and a total of 148 bushels per acre for the two years of this experiment.

This exceeded the no-fertilizer treatment by an average of 8 bushels of U. S. No. 1 onions.

Similar plats unfertilized initially, but receiving a side dressing in January of 181.8 pounds of 11-48-0 per acre (containing the same amount of nitrogen as 100 pounds of 20% ammonium sulphate) yielded an average of 104 bushels of U. S. No. 1 onions per acre, and an average total yield of 178 bushels. Apparently the phosphoric acid contained in this fertilizer helped the onions more than nitrogen applied alone.

While nitrogenous side dressings on onions previously unfertilized are usually at least slightly beneficial, the practice of side dressings in general is not as effective in increasing yields as suitable fertilizer applied before the onion plants are set out. Where a complete fertilizer has been applied before planting, nitrogenous side dressings are likely to reduce yields.

## EFFECT OF FERTILIZER ON OTHER CHARACTERISTICS

### Fertilizer and Earliness

Although onions require a certain length of day before they will bulb up, and hence cannot be unduly hastened toward maturity, they will respond somewhat to other factors, and when the length of day ceases to be a limiting one, they may mature early or late according to these various conditions. Normally in any given locality and with the same variety this variation in time of maturity will not be greater than about two weeks. As it is frequently to the growers' advantage to harvest as early as possible because prices sometimes fall from day to day, any factor contributing to earliness is important.

All the plats in any one series of the Station's experiments were always harvested on the same day. The complexity and extensiveness of the experiments, in addition to other considerations, made this procedure a practical necessity, aside from the fact that by such harvesting no treatment had the advantage of others in being able to grow for a longer period.

From general observations it was obvious that the onions in certain treatments were always ready to harvest before those in other treatments. Onions receiving fertilizer mixtures which caused them to produce higher yields were usually ready to harvest before onions which received less favorable fertilizer applications. In the case of certain treatments, the onions could usually have been harvested a week to ten days ahead of most other treatments. These early treatments were the following: 600 pounds of 6-18-6 fertilizer; 900, 1200, and 1800 pounds of 6-12-6 fertilizer; 1200 and 1800 pounds of 6-12-0; and 327½ pounds of 11-48-0 fertilizer.

Onions growing on plats receiving no fertilizer, or on plats receiving mixtures which did not especially increase yields, tended to mature later. Hence with such treatments yields were not only lighter but under prac-

tical commercial conditions the possibilities are that the market price would often be lower by the time such onions were ready to harvest.

It would seem that the onion plant if given favorable conditions, such as those created by an adequate amount of the suitable fertilizer applied before the plant is set out, will grow vigorously throughout the winter months. Then, when the days lengthen sufficiently, it at once begins to bulb. The bulb is likely to become fairly large—hence increasing yield. With the plant which is poorly fertilized the growth is much less vigorous, the tops never become as large, and when the length of day favors bulb formation the process gets under way slowly and usually slightly later than in the case of the more vigorous plant. In all of the four years of these experiments differences in color, size, and general appearance of the top growth due to the various treatments were noticeable within a month of the time when the plants were set out, and these differences became increasingly apparent as the weeks and months went by. This striking visual evidence combined with the final results of yield and date of maturity indicated the value of the early application of the desirable fertilizer.

#### **Grades as Affected by Fertilizer**

Yield in itself is not the only result in which a grower is interested. The yield may be good and yet the quality of the product so poor that the possibilities of selling it at a profit are very limited. The percentages of the total crop that fall into the various grades gives an indication of the quality of the crop. These grades are Jumbo, U. S. No. 1 (medium), boilers, and culls. The first three grades are size groups, and all are really U. S. No. 1, but as in the trade U. S. No. 1 commonly refers to the medium grade which is rarely mentioned as such, it seemed desirable to use the terms in the sense in which they are regularly used.

In reporting the yields of the various tests in terms of U. S. No. 1 as well as total, the quality of the crop has already been indicated to some extent. In Table 9, however, the yields of all the grades harvested from the fundamental series during four years are given, and hence it is possible to see what effect, if any, a particular fertilizer had on any given grade.

It is evident that fertilizer is not the only factor having an effect on quality. In 1931-32 the percentage of U. S. No. 1 onions was rather low in general, and the percentage of boilers rather high, as compared with 1932-33 when the percentage of U. S. No. 1 was fairly high, and the percentage of boilers low. In 1931-32 the new land may have had a retarding effect on the growth of the onions, or they may have been harvested somewhat prematurely. The serious February freeze came in the 1932-33 season, yet as indicated above, the percentages of U. S. No. 1 onions were greater that year. Culls which are largely splits and doubles were in general present in larger numbers in 1932-33, presumably because of the freeze.

As has been pointed out before, the pink root disease became a serious factor in 1934-35. The growth of the onions was greatly retarded by it, and large numbers of bulbs which did not make the U. S. No. 1 grade on account of small size had to be classified as boilers. It is interesting to

**Table 9. The effect of fertilizer on the percentages of the total yield falling in the various grades (see next page)**

Fertilizer used	1931-32				1932-33			
	Jumbo	U. S. No. 1	Boilers	Culls	Jumbo	U. S. No. 1	Boilers	Culls
<b>Nitrogen series:</b>								
0-12-6.....	0	38.9	38.4	22.7	0.6	73.1	15.3	11.0
3-12-6.....	0	47.5	36.4	16.1	1.3	78.2	4.1	16.3
6-12-6.....	0	56.3	26.4	17.3	2.6	72.0	3.3	22.1
9-12-6.....	0	59.3	25.7	15.0	1.8	72.9	3.2	22.0
<b>Phosphoric acid series:</b>								
6-0-6.....	0	31.6	49.6	18.8	0	77.2	20.3	2.5
6-6-6.....	0	45.0	37.8	17.2	1.6	79.7	7.6	11.1
6-12-6.....	0	66.9	23.8	9.3	4.7	68.0	4.2	23.2
6-18-6.....	0	66.0	21.9	12.1	2.2	65.3	2.2	30.2
<b>Potash series:</b>								
6-12-0.....	0	51.6	34.2	14.2	5.9	64.8	4.8	24.4
6-12-3.....	0	58.3	27.0	14.7	2.4	80.9	5.9	10.9
6-12-6.....	0	55.4	31.4	13.2	1.0	75.2	4.9	18.9
6-12-9.....	0	53.1	27.7	19.2	1.1	71.4	3.5	24.1
<b>Complete fertilizer series:</b>								
No fertilizer.....	0	38.6	39.9	21.5	0	76.9	18.6	4.5
300 lbs. of 6-12-6.....	0	52.7	31.1	16.2	1.7	82.3	5.8	10.3
600 lbs. of 6-12-6.....	0	58.2	29.6	12.2	0	76.4	3.7	19.4
900 lbs. of 6-12-6.....	0	69.1	21.4	9.5	6.3	63.7	0.9	29.0
1200 lbs. of 6-12-6.....	0	78.6	13.7	7.7	0.7	65.0	2.9	31.5
1800 lbs. of 6-12-6.....	0	84.0	9.4	6.6	3.1	56.7	3.4	36.8

note that the percentage of culls was in general no greater than normal in 1934-35. The greatest tendency toward culls was evident in 1932-33, the year of the severe freeze, rather than in 1934-35, a year of severe pink root infection. The low percentages of U. S. No. 1 onions in 1934-35 of course lowers the average percentage for the four seasons. This average should not be considered typical for onions grown year after year on land free from pink root.

Although the effect of fertilizer on quality is nowhere extremely striking, it is nevertheless evident. In an average of four years there was a tendency toward a greater percentage of U. S. No. 1 onions from the fertilizers containing a greater percentage of nitrogen. The U. S. No. 1 onions averaged 56.8 per cent for the four years from the 9-12-6 mixture and only 48.8 per cent from the 0-12-6 mixture (Table 9). The intermediate treatments 3-12-6 and 6-12-6 had intermediate percentages of U. S. No. 1 onions of 54.0 and 55.2 respectively. This trend toward more U. S. No. 1 onions with more nitrogen in the fertilizer was more obvious in 1931-32 and 1934-35 than in any other years. In 1931-32 the percentages of both boilers and culls tended to fall as the amount



of nitrogen was increased; in 1934-35 only the percentage of the boilers fell, and then the fall was not well correlated with the increase in nitrogen.

In the first season, 1931-32, an increase of phosphoric acid from 6-0-6 up through 6-6-6 to 6-12-6 had a remarkable effect in increasing

**Table 9. The effect of fertilizer on the percentages of the total yield falling in the various grades—Continued**

1933-34				1934-35				Average			
Jumbo	U. S. No. 1	Boilers	Culls	Jumbo	U. S. No. 1	Boilers	Culls	Jumbo	U. S. No. 1	Boilers	Culls
1.1	68.4	16.2	14.3	0	14.6	70.8	14.6	0.4	48.8	35.2	15.6
0.3	69.5	16.6	13.6	0	20.6	52.9	26.5	0.4	54.0	27.5	18.1
0.3	71.4	14.5	13.8	0	21.7	60.9	17.4	0.7	55.2	26.3	17.8
0	70.3	17.7	12.0	0	24.7	61.6	13.7	0.5	56.8	27.0	15.7
0	51.6	34.7	13.7	0	11.1	75.0	13.9	0	42.9	44.9	12.2
0.8	66.8	23.3	9.3	0	18.3	69.0	12.7	0.5	52.4	34.2	12.9
0	67.6	22.5	9.9	0	26.9	57.7	15.4	1.2	57.4	27.0	14.4
0.3	69.8	15.3	14.6	0	21.6	62.2	16.2	0.6	55.7	25.4	18.3
0	69.6	15.6	18.6	0	25.4	57.3	17.3	1.5	52.9	28.0	17.6
0.3	69.8	15.0	14.9	0	23.3	61.7	15.0	0.7	58.1	27.4	13.8
0.4	69.4	16.0	14.2	0	19.1	69.1	11.8	0.4	54.8	30.3	14.5
0	69.9	14.0	16.1	0	25.9	57.6	16.5	0.3	55.1	25.7	18.9
0	58.7	30.5	10.8	0	12.0	62.0	26.0	0	46.6	37.7	15.7
0	64.2	22.0	13.8	0	23.3	58.9	17.8	0.4	55.6	29.5	14.5
0	73.0	16.7	10.3	0	21.0	63.2	15.8	0	57.3	28.3	14.4
0	67.8	13.3	18.9	0	25.3	53.2	21.5	1.6	56.5	22.2	19.7
0.3	71.0	11.9	16.8	0	25.3	59.5	15.2	0.2	60.0	22.0	17.8
0	72.4	8.8	18.8	0	22.2	50.0	27.8	0.8	58.8	17.9	22.5

the percentage of U. S. No. 1 onions. In the 6-0-6 treatment 31.6 per cent of the onions were U. S. No. 1. The 6-18-6 mixture resulted in 66 per cent, practically the same as for the 6-12-6. Most of this gain in percentage of U. S. No. 1 was lost in the boilers, which fell from 49.6 per cent in the 6-0-6 treatment to 23.8 per cent in the 6-12-6 treatment. In 1932-33, the season of the severe freeze, the numbers of U. S. No. 1 onions in the phosphoric acid test fell off as the phosphoric acid was increased. The better fertilized onions seemed unable to withstand the low temperatures, probably because they were more succulent. As the percentage of the U. S. No. 1 grade fell off with increases of phosphoric acid, the percentage of culls increased. The 6-18-6 treatment had 30.2 per cent of its yield in culls, while from the 6-0-6 treatment only 2.5 were in that grade. The percentage of boilers also fell off with increases of phosphoric acid. The average of the four years, even with the adverse 1932-33 season included, indicates that phosphoric acid has more effect on quality in terms of percentage of U. S. No. 1 onions than either nitrogen or potash. With the exception of 1932-33, the culls remained

fairly constant in all treatments, but the percentages of boilers tended to decrease as the percentages of U. S. No. 1 onions increased.

Of the three nutrients, potash had the least effect on quality. On the average of four years the U. S. No. 1 onions ranged between 52.9 and 58.1 per cent with no correlation at all between the amount of potash and the percentage obtained. The boilers and culls were likewise apparently not influenced.

The amount of complete fertilizer had practically as much effect on quality as phosphoric acid did. In 1931-32, only 38.6 per cent of the onions from the no-fertilizer treatment were U. S. No. 1 grade, but 84 per cent of those from the 1800 pound an acre treatment belonged to that grade. In that year as the amount of fertilizer was increased the percentage of U. S. No. 1 onions increased, and the percentages of both boilers and culls decreased.

In 1932-33 the freeze resulted in what amounted to almost a reversal of the results obtained in 1931-32. In the heavily fertilized treatments there were many culls (mostly splits and doubles), and a correspondingly smaller amount of U. S. No. 1 onions. In the no-fertilizer plats 4.5 per cent of the onions were culls, but in the plats receiving 1800 pounds of 6-12-6 fertilizer 36.8 per cent were culls.

Never since the first year has the 1800 pound per acre treatment produced such a high percentage of U. S. No. 1 onions as it did in that year—84 per cent. It will be recalled that after the first year this treatment did not increase yields as it had at first.

Apparently the most desirable fertilizer for a given situation will not only increase the yield as a whole but cause a larger proportion of it to fall in the U. S. No. 1 grade than otherwise would do so with a less desirable fertilizer.

### Fertilizer and Keeping Quality

It is not a common commercial practice to store Bermuda onions for any length of time in the Winter Garden area. Even cold storage is rarely, if ever, resorted to. The best market is usually at the time of harvest, and the onions are disposed of at that time. In addition to this, Bermuda onions have a reputation as poor keepers.

Although storage, at least planned storage, is not a common practice, growers are occasionally forced to hold a portion of their onion crop a week or two because of market or weather conditions. In other words, while storage is not usual in Bermuda onion production, and hence the factors which affect it are of less importance to the grower than those factors which affect yield and quality, it is nevertheless a matter on which any available information is pertinent.

In Tables 10 and 11 are given the dates on which the various samples in storage were examined and the percentages of onions which had to

be discarded on those dates as unmarketable. The results of 1932 show somewhat more definite trends than those of 1933. The proportion of nitrogen in the fertilizer mixture, and the total amount of complete fertilizer, seemed to have the most effect on the keeping quality of the onions. Phosphoric acid and potash had little effect.

In 1932 the onions which had come from the plats receiving no nitrogen (0-12-6) decayed the slowest, and by October 13, after 175 days, only 22 per cent had been removed as unmarketable, while the samples coming from the 9-12-6 plats had lost 54 per cent (Table 10).

**Table 10 Percentages of onions placed in storage, no longer marketable, 1932**

	June 1 (41 days)	June 16 (56 days)	July 7 (77 days)	August 2 (103 days)	August 23 (124 days)	Sept. 9 (138 days)	Oct. 13 (175 days)
<b>Nitrogen series:</b>							
0-12-6.....	0	0	4	8	12	16	22
3-12-6.....	0	0	8	12	24	24	36
6-12-6.....	8	10	16	20	22	22	48
9-12-6.....	0	2	2	22	32	44	54
<b>Phosphoric acid series:</b>							
6-0-6.....	4	4	8	15	21	24	37
6-6-6.....	0	0	0	12	16	28	44
6-12-6.....	3	5	15	16	19	20	34
6-18-6.....	3	4	10	18	32	38	48
<b>Potash series:</b>							
6-12-0.....	1	4	11	17	29	23	41
6-12-3.....	0	1	7	17	21	21	32
6-12-6.....	4	4	12	17	25	37	51
6-12-9.....	4	4	7	12	25	33	45
<b>Complete fertilizer series (6-12-6):</b>							
No fertilizer.....	4	8	13	20	27	29	45
300 pounds.....	10	14	20	32	32	36	33
600 pounds.....	0	2	12	30	36	48	58
900 pounds.....	0	2	10	28	36	40	64
1200 pounds.....	4	6	16	26	42	44	60
1800 pounds.....	12	20	40	52	68	76	96

The samples coming from the plats receiving the 6-12-6 fertilizer had lost 48 per cent, and those from the 3-12-6 plats had lost 36 per cent.

In 1933 the trend was not as clear cut, although it was in the same direction (Table 11). The samples taken from the 0-12-6 plats decayed on the whole the slowest, and at end of the storage period (October 23, 181 days) had the only 52 percent (the lowest) removed. For some reason the samples from the 6-12-6 plats of the nitrogen series ended with the highest percentage of loss—77 per cent, and those from the 9-12-6 plats were the next highest—68 per cent. In comparison with samples from the 6-12-6 plats of other series, those of the nitrogen series lost a higher percentage and hence were somewhat out of line.

The highest percentage of decay (96 per cent) in 1932 occurred in the samples taken from the plats receiving 1800 pounds of 6-12-6 per acre (Table 10). While the no-fertilizer treatment did not have the smallest amount of decay, it was considerably lower (45 per cent) than

the 1800 pound treatment. In general, decay was more rapid and ended at a higher percentage as the amount of complete fertilizer increased. This was even more noticeable in 1933, for in that year there was an increase in decay with every added increment of fertilizer when the final score was taken on October 23 after 181 days of storage (Table 11).

Table 11. Percentages of onions placed in storage, no longer marketable, 1933

	June 1 (37 days)	June 13 (49 days)	June 28 (64 days)	July 7 (72 days)	July 21 (87 days)	Aug. 5 (102 days)	Aug. 18 (115 days)	Sept. 1 (129 days)	Sept. 20 (148 days)	Oct. 3 (161 days)	Oct. 23 (181 days)
<b>Nitrogen series:</b>											
0-12-6.....	0	1	1	1	7	15	25	31	36	39	52
3-12-6.....	0	1	2	3	6	11	19	23	41	45	54
6-12-6.....	4	4	9	11	15	22	36	44	62	62	77
9-12-6.....	3	4	6	7	12	19	30	34	55	59	68
<b>Phosphoric acid series:</b>											
6-0-6.....	0	3	5	6	15	20	31	38	50	68	71
6-6-6.....	9	9	9	9	12	17	21	32	46	52	62
6-12-6.....	0	1	3	3	8	18	23	28	40	46	56
6-18-6.....	5	6	8	9	18	26	35	41	56	63	72
<b>Potash series:</b>											
6-12-0.....	7	8	8	8	12	22	36	43	54	59	72
6-12-3.....	3	6	6	6	10	20	28	36	43	52	61
6-12-6.....	2	3	5	7	15	23	28	34	48	59	67
6-12-9.....	6	9	12	13	22	34	36	43	47	52	60
<b>Complete fertilizer series (6-12-6):</b>											
No fertilizer.....	1	2	3	4	8	12	15	16	26	29	42
300 pounds.....	3	5	6	6	11	16	25	34	38	40	49
600 pounds.....	1	1	1	6	9	12	18	21	34	40	50
900 pounds.....	4	4	7	11	12	20	22	26	35	49	65
1200 pounds.....	3	3	4	6	13	24	29	37	47	56	68
1800 pounds.....	4	7	11	14	32	41	46	54	64	74	78

It is possible that nitrogen is the only nutrient involved. The greater amount of decay in the samples coming from the plats receiving large amounts of complete fertilizer may be due to the larger amount of nitrogen present in such applications. If phosphoric acid and potash have no effect on the keeping quality one way or the other, they may not have any deterring influence on the effects of the large amounts of nitrogen automatically present in large applications of complete fertilizer.

While the results of this storage test probably cannot be taken as conclusive, they are at least indicative of trends. It is common knowledge that nitrogen frequently causes succulent growth, and if the bulbs grown with more nitrogen are more succulent, it would not be expected that they would store as well.

Phosphoric acid was the most beneficial nutrient in increasing yields and in increasing the percentages of U. S. No. 1 onions. It would seem that the keeping qualities of the onions would not be reduced by larger applications of this nutrient. This storage study indicates, however, that it is probably a wise procedure to avoid storage when large amounts of complete fertilizer have been used.

## DISCUSSION AND RECOMMENDATIONS

Most of the experiments described and discussed have rather clear cut results. The question now is: How far can these results be applied to practical commercial practice? Before any specific recommendations suggested by these results, a few general recommendations need to be considered.

First of all, there is no series of fertilizer practices adapted to all growers, all soils, and all situations. Before any decision can be made the soil and its previous handling must be known. With these facts in mind, the results of the Station's experiments can be studied and the most promising practices decided upon. After this decision, the question of cost still has to be considered. Some methods of handling the crop are more costly than others. There is more to lose from an expensive treatment than there is from a cheaper one in the event of a complete crop loss. On the other hand with any venture there is always a possibility of complete loss because of a catastrophe of some kind. Whatever the price received per bushel for the harvested onions, as long as it is above the cost of harvesting the more of them there are per acre the less the net loss, or the greater the profit.

Results reported in Table 8 can be used as an example to illustrate this point. For the two harvest years 1934 and 1935 the treatment in which 600 pounds of 6-12-6 fertilizer have been applied to the ground before the onion sets have been set out made an average yield of 169 bushels of U. S. No. 1 onions without any further fertilizer application. Growing and harvesting costs amounted to about \$104.20\*. If 75 cents† per bushel were received for these onions, the net return would be about \$22.55 an acre. In contrast with this, the average yield for the same two seasons from the treatment receiving no fertilizer initially, but instead two side dressings with nitrate of soda later (a common commercial practice), was 76 bushels of U. S. No. 1 onions. Growing and harvesting costs amounted to about \$70.30\*. If 75 cents a bushel were received for these onions, there would be no net profit at all, but a loss of \$13.30 per acre. Had the price per bushel been \$1.00, then there would have been a net return in this last case of \$5.70 an acre, but the net gain from the 6-12-6 treatment would have risen at this price to \$64.80 per acre.

**Importance of Ratio.** Another point to be considered when adapting the results of these experiments is that the exact materials and formulas used by the Station do not have to be used to obtain success. They were chosen because they were available, and because many

\*Estimated costs common to both treatments: Seed \$4.00, transplanting \$12.50, irrigation \$18.00, cultivation \$5.00, total \$39.50; costs peculiar to each treatment: fertilizer in 6-12-6 treatment \$12.00, labor of applying it \$2.00, harvesting and bags for 169 bushels \$50.70; fertilizer for side dressing treatment \$3.00, labor of 2 applications \$5.00, harvesting and bags for 76 bushels \$22.80.

†An arbitrary average price for U. S. No. 1 onions. In the 1933-34 season the price sank to 50c or lower; in 1931-32 it was up to \$2.55 and higher; in 1934-35 it was mostly above \$1.50.

farmers were using them in some form or other. Taking the amounts, formulas, and yields obtained in these experiments, it is possible to figure out entirely new amounts and different formulas. The important thing is to get the right *balance* of nutrients in the fertilizer used. This is expressed by the ratio of the formula; for example, the formulas 6-12-6 and 10-20-10 have a ratio of 1-2-1; while 6-18-6 and 5-15-5 have a 1-3-1 ratio, and so on. Different situations and conditions may require different ratios.

**Fertilizer for New Land.** Phosphoric acid seems to be the most important nutrient, nitrogen probably next, and potash the least important. On new land or on land which has onions for the first time, and has never been fertilized, 900 to 1200 pounds per acre of 6-18-3 would probably produce good results. In this formula the ratio of nitrogen to phosphoric acid is 1 to 3; this gives more phosphoric acid than the 6-12-6 formula. The small amount of potash as represented by the figure "3" is included because in the first year on new land potash increased yields slightly. Present in slightly greater or smaller amounts potash would not be expected to affect yields greatly. Hence such applications as 900 to 1200 pounds of 5-15-0, 5-15-5, or 300 to 350 pounds of 11-48-0 should all give satisfactory results. A 11-48-0 formula is closer to a 1-4-0 ratio than it is a 1-3-0, but nevertheless this particular formula has given satisfactory results at this Station (Table 4).

**Fertilizer for Old Land.** Where onions are being grown for the second year on the same land any of the above applications should be satisfactory, if no fertilizer was used the first year. If fertilizer including potash was used, then no more potash need be added for several years. An application of 600 to 900 pounds of 6-18-0, 5-15-0, or any equivalent amount of fertilizer with a 1-3-0 ratio, should give good results. Such formulas should be cheaper, as they exclude potash.

**Superphosphate alone often valuable.** On new land, or on previously fertilized land, it is better to add superphosphate alone rather than to add no fertilizer at all. An application of 350 to 400 pounds per acre of 20 per cent superphosphate is recommended. Superphosphate is one of the cheapest of the nutrients, and also the most effective. Amounts larger than 400 pounds are hardly profitable. Where a higher grade material (i. e., one with a larger percentage of phosphoric acid) is used, the amount per acre should be reduced proportionately.

Where a green manure has been plowed under, the superphosphate alone might often be expected to be all that is needed to make the fertilization a complete and economical one.

**Apply Fertilization Before Transplanting.** The time of application of any fertilizer seems very important. All the results at the Station indicate that the earlier the onions can make use of the fertilizer the more vigorous, healthy, and heavy yielders they will be. Fertilizer of any kind should be put in the soil before the plants are set out. If as

much as 1200 pounds is going to be applied anyway, then it is better and cheaper to put all of it at the beginning than to make several applications. Yields will be higher.

**Side Dressings of Doubtful Value.** Applying nitrogenous side dressings in January and February to onions previously fertilized with a complete fertilizer may reduce yields instead of increase them. Such side dressings applied to onions which have as yet received no fertilizer may increase yields to some extent. Such a late application of fertilizer might better be a more balanced material such as 11-48-0, which happens to be fairly soluble. However, more good can be done not only in increasing yields but also in making plants more vigorous and better able to stand up under attacks of thrips and pink root, by putting the fertilizer in the ground early so the young transplanted seedlings can use it then, rather than later.

**Irrigation and Side Dressings.** Irrigation is linked with fertilizer practices. There may be some surprise that side dressings with nitrate and ammonium sulphate reduced yields instead of increasing them at the Station in 1933-34 and again in 1934-35. It is possible that this would not always happen. However, in line with the results of the irrigation experiments of previous years (5, 9) a minimum of irrigation was practiced on these plats. Frequent irrigation will leach out soluble salts such as nitrate. Hence, under such conditions, sodium nitrate or ammonium sulphate side dressings may replace the lost nitrogen. Where there is not too much irrigation, the additional nitrogen may make the fertilizer balance unfavorable and hence affect the plants and final yield adversely. Avoiding over-irrigation may not only save water and labor expense, but reduce the necessity of nitrogen side dressings also, and finally increase yields. While this suggestion is without all the supporting facts at this time, it is nevertheless worthy of careful thought in view of the results so far obtained.

**Fertilizer on Heavier, Darker Soils.** All of the Station's experiments were on a Webb fine sandy loam. On heavier soils the needs are somewhat different. Judging by analyses and other information, potash is still as little needed on those soils as it is on sands. In general, 200 to 300 pounds less of mixtures such as 6-12-6 and 5-15-5 can probably be used on the heavier, darker soils than would be necessary on the sands and sandy loams. Superphosphate alone should probably still be applied at around 300 to 400 pounds per acre, as in all the soils phosphoric acid is always becoming "tied up" and unavailable.

**Changing Fertilizer Program May Be Desirable and Profitable.** Since the application of fertilizers one year may change the need of the soil the following year, the fertilizer program should not be an invariable one under practical commercial conditions. There are a number of instances in these fertilizer tests of certain fertilizer mixtures failing to produce year after year the high yields attributed to them in the first season. Evidently sufficient residues are left in the soil so that in

another year another large application is no longer as effective as the first. While such applications may be very profitable the first year on new land (or on previously unfertilized land), economies can be effected in succeeding years by applying smaller amounts, or fertilizers with other formulas.

**Proper Fertilizers Applied Early May Lead to Earlier Crop.** The well-fertilized onion plant is very likely to bulb up as soon as the day becomes long enough. This is a distinct advantage as the early prices are sometimes higher than the later ones. The poorly fertilized onion plant may not bulb up promptly even after light conditions become favorable.

**Amount of U. S. No. 1 Grade Increased by Proper Fertilizer.** The all important yield of U. S. No. 1 onions is, under normal conditions, increased by the same fertilizers which increase yields. That is, not only is the total yield increased, but the percentage of this total classifying as U. S. No. 1 is generally larger than it is with a less desirable fertilizer. It is such tendencies as these that under practical conditions help to make the correct fertilizer practice a profitable venture.

**Combating Pink Root and Thrips.** Land known to be infested with pink root (*Fusarium malli*) should be avoided if possible when planting onions. No matter how well such land is fertilized the crop is still likely to be a failure from the commercial point of view. However, even with a heavy infestation of the disease, yields are very likely to show the same trends in differential fertilizer treatments as they would if there were no disease.

If a crop of onions has received satisfactory application of fertilizer, damage by thrips (*Thrips tabaci*) will usually be reduced to the point where the chances of obtaining a profitable harvest are greatly increased. In 1933-34 and again in 1934-35, two seasons in which thrips have been a major problem of the onion grower, yields of U. S. No. 1 onions of over 200 bushels to the acre have been obtained from various treatments at the Station.

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#### SUMMARY

The results obtained in the fertilizer and cultural experiments with Yellow Bermuda onions at the Winter Garden Substation over a period of four years on Webb fine sandy loam lead to the following conclusions:

1. Phosphoric acid is the most needed nutrient, since increasing its



amount through the successive formulas 6-0-6, 6-6-6, 6-12-6, 6-18-6, increased yields to a greater extent than was recorded in the corresponding similar series with nitrogen and potash. Withholding phosphoric acid entirely (6-0-6) caused lower yields than any other treatment including the no-fertilizer treatment. Like nitrogen, phosphoric acid can accumulate so that high applications of it after several years on the same land are not as effective as at first. During the four years of these tests, however, phosphoric acid was always more effective than nitrogen.

2. Nitrogen is a needed nutrient since increasing its amounts through the successive formulas 0-12-6, 3-12-6, 6-12-6, 9-12-6 increased the yields of U. S. No. 1 onions as well as the total yields obtained. However, this effect tended to decrease in successive years.

3. Potash is the least essential of the three chief nutrients. It increased yields slightly the first year, but thereafter tended to decrease them. Results were never as consistent with potash as they were with either nitrogen or phosphoric acid.

4. On new land, increasing amounts of complete fertilizer (6-12-6) from 0 to 1800 pounds per acre increased the yields of U. S. No. 1 onions as well as the total yield. Applications above 1200 pounds are hardly profitable, however, even the first year. In succeeding years, amounts above 900 pounds per acre are rarely profitable.

5. Ammonium sulphate applied alone in amounts greater than 180 pounds (equivalent to 600 pounds of 6-0-0) are hardly profitable. Even this amount applied for the first time to new land may decrease yields rather than increase them.

6. Twenty per cent superphosphate applied alone is more effective than ammonium sulphate alone. Increasing the application from 360 to 1080 pounds per acre will usually increase yields, but amounts much greater than 360 pounds are usually not profitable. Superphosphate alone is a useful and economical material.

7. Nitrogen and phosphoric acid in combination at a rate equivalent to 600 pounds of 6-12-0 fertilizer are usually more effective in increasing yields than either nutrient is by itself. At rates equivalent to 1200 and 1800 pounds of 6-12-0 they are often less effective than superphosphate alone.

8. Side dressings of any kind are not as efficient, economical, or effective as fertilizer applied before transplanting.

9. The various nitrogen carriers may vary from year to year in effectiveness as judged by the yields obtained. Nitrate of soda, sulphate of ammonia, and cottonseed meal have all given fairly favorable results when combined with superphosphate and muriate of potash. Cyanamid has rather consistently resulted in lower yields than other forms of nitrogen in equivalent amounts.

10. Cottonseed meal applied alone at a rate of 510 pounds per acre is not a satisfactory practice in terms of the yields produced at anything like normal prices.

11. The 11-48-0 fertilizer applied at around 325 pounds per acre can be expected to produce yields in the neighborhood of those produced by 600 pounds of 6-12-6 fertilizer.

12. The 16-20-0 fertilizer applied at a rate as low as 225 pounds per acre is not the best for new land or for land previously unfertilized. In the second year of a fertilizer program applied at the same rate, it is likely to produce yields in the neighborhood of those produced by 600 pounds of 6-12-6, and prove to be an efficient, economical fertilizer.

13. Other conditions being equal, onions receiving adequate amounts of a properly balanced fertilizer will be in some seasons, as much as a week to 10 days earlier than unfertilized onions.

14. In terms of the percentage of the total yield that classifies as U. S. No. 1 onions, the quality of the crop is affected mostly by phosphoric acid, to a less extent by nitrogen, and least by potash.

15. Onions taken from land fertilized with materials high in nitrogen are likely to decay quicker in storage than onions taken from land which received fertilizer with a low nitrogen content.

16. Although correct fertilizer practices are likely to result in at least fair yields in spite of thrips, it is difficult to obtain anything but low yields whenever the soil harbors the pink root disease.

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