T H E S I S

THE EFFECT OF NITROGEN, PHOSPHATE AND POTASSIUM ADDITIONS TO THE SOIL ON YIELD AND ROOT ROT OF POD PEAS

Submitted by

Edward O. Olson

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY

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CREDITS

A. M. Binkley
In Charge of Thesis

APPROVED A. M. Binkley
Head of Department

Examination Satisfactory

Committee on Final Examination

W. A. Kreutzer   Robert Gardner

J. L. Forsberg   J. G. McLean

V. E. Iverson
Dean of the Graduate School

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THE EFFECT OF NITROGEN, PHOSPHATE AND POTASSIUM ADDITIONS TO THE SOIL ON YIELD AND ROOT ROT OF POD PEAS

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INTRODUCTION

The production of pod peas is an important part of Colorado's agriculture. As shown in Table I pod peas were grown on 14,500 acres in Colorado in 1942, with an estimated value of $1,834,000. Pod peas were harvested from 13,050 acres in the San Luis Valley area in 1942.

Table 1.--COLORADO ACREAGE, PRODUCTION, AND VALUE OF GREEN PEAS FOR TABLE USE. (9)/1

Year	Acres Har-vested	Yield per acre bushels	Pro-duction bushels	Price per bushel	Value	Value per acre
1938	8,600	95	817,000	$ .75	$ 613,000	$71.28
1939	9,300	110	1,023,000	.75	767,000	82.47
1940	11,500	120	1,380,000	.80	1,104,000	96.00
1941	13,500	130	1,755,000	.70	1,228,000	90.96
1942	14,500	110	1,595,000	1.15	1,834,000	126.48

/1 Numbers in parentheses refer to Literature Cited.

The root rots of peas (*Pisum sativum* L.) are a serious consideration in growing pod peas in the San Luis Valley and other sections of Colorado, as well as in other commercial pea growing areas of the United States. In fields affected by these diseases, emergence of the seedlings is reduced, many of the plants die before maturity, the number of pickings is reduced, and the yield of marketable peas is decreased.

Although the exact amount of loss caused by root rots is difficult to determine, the reduction in yield is considerable. The average yearly loss caused by root rots in Colorado has been estimated at ten per cent of the total crop. This loss amounted to $183,400 in 1942.

The term, "root rot", has been applied to a group of diseases caused by several different parasites that produce somewhat similar symptoms. The most obvious symptom is a rotting of the underground parts of the plant. In some instances the lower part of the stem is involved.

Several types of root rot have been found in Colorado, but three fungi, *Fusarium*, *Rhizoctonia*, and *Pythium*, seem to be responsible for most of the damage. Of these, one species, *Fusarium solani* (Mart.) v. *martii* (App. et Wr.) Wr. f. 2 Sny. (38) is probably the most important parasite (11).

The maintenance of profitable yields is related to the fertility of the soil on which the peas are grown. Not only does the fertility of the soil affect the tolerance and susceptibility of some plants to disease, but it is also related to their recovery from infection. (16) There are very few cases, however, where a parasitic or virus disease can be completely controlled by fertilizer treatments alone. As a rule, a combination of fertilizer treatments with proper cultural practices and other protective measures, such as seed treatment or spraying is required to grow a profitable crop in a disease infested locality. Tests in New York (16) on the production of canning peas have shown that the full value of either fertilizer or seed protectant was realized only when they were used together.

A review of the literature revealed that a great deal of work had been done on the control of root rot of peas. However, no effective control of the disease has been devised. Because soil fertility trials have received little attention as a control measure, a series of experiments was conducted to test the value of fertilizer applications to the soil as a means of reducing losses due to root rot. Preliminary studies in Colorado during the period of 1938-1942 indicated that the emergence of peas grown in soil infested with root-rotting fungi was affected by fertilizer applications, but little information was available regarding the effect on yield. The purpose of the 1943 trials was to determine the effects of fertilizer applications on the emergence, yield, and number of living plants at picking time.

REVIEW OF LITERATURE

The response of peas to fertilizer has varied with the locality, the soil fertility level, placement, variety, and other factors. Jodidi and Boswell (15) in Virginia noted a yield increase resulting from application of superphosphate. Boswell (2) in Maryland emphasized the importance of using more nitrogen than was commonly used. Davis, Cook, and Baten (10) observed significant reductions in yield from the use of 4-16-8, 0-20-0, and 0-16-8 fertilizers. Bowers and Mahoney (3) in Maryland found that the yield response from fertilizers varied with the fertility level of the soil.

The response of peas to fertilizer, measured in terms of stand and yield, has varied with the placement of the fertilizer. New York studies by Sayre and Cumings (32) showed that placement of the fertilizer in contact with the seed is injurious, but little injury may result if the fertilizer and seed are sown in separate operations. Superphosphate alone was less injurious than a complete fertilizer when used in contact with the seed. Placement above the seed was slightly injurious and reduced yield. Placement two and a half inches to the side and one inch below the seed proved advantageous. Parker (26), Parker and Oliver (27), Division of Vegetable Crops, Geneva, N. Y. (25) and Musbach (19) have stated that the amount of injury is primarily dependent upon the concentration of fertilizer salts, which in turn is dependent upon the soil moisture. Sayre and Clark (31), working with beans, showed that ammonium sulfate additions to the soil were very injurious to the seeds and roots when first applied. Superphosphate reduced the germination of seeds planted in contact with the fertilizer when first applied, but it did have a stimulating effect on root growth. The potash fertilizers had no stimulating effect on root growth. Potassium chloride dissolved rapidly and reduced the germination of seeds planted in contact with the fertilizer bands and also inhibited root growth until the concentration of soluble salts had been sufficiently reduced by diffusion so that they no longer caused plasmolysis.

The advantages of side placement of fertilizer for beans were shown by Millar (18), Davis (10), Sayre (30), and others.

The addition of fertilizer to the soil affects not only yield, but the chemical composition of the plant. Sayre and Nebel (33), Sayre, Willamen, and Kertesz, (34) have shown that the amount of calcium in the pea ovules decreases as the potassium increases. Musbach and Sell (20) found that additions of potash fertilizer diminished the concentration of calcium in the seed coats of peas. Sayre, Willamen, and Kertesz (34) noted that where calcium was added to the soil, increased root rot resistance and higher yields developed. They attributed this response to a thicker and tougher cell wall formed when calcium was added. Carolus (6) observed that potassium in large amounts depressed the absorption of nitrogen by lima beans. Post (28) stated that the hardening of greenhouse sweet peas was caused by a high concentration of nitrate in the soil or developed when the plants were grown in sand and supplied with a nutrient solution deficient in phosphate. Most of the hardening in sweet peas was due to an excess of nitrates or of total soluble salts in the soil.

The relation of soil fertility to diseases of plants, except for a few instances, is not clearly defined. Chester (7), however, has described two general groups of plant diseases. Causal agents of the first group (the rusts, powdery mildews, and certain virus diseases) attack the most vigorous hosts. Causal agents of the second group (including numerous root rot, canker, and leaf spot diseases) attack only weakened plants.

Wingard (39), in a review of the literature dealing with the nature of disease resistance of plants, pointed out that "plant nutrition may modify the histological or morphological structure of the plant in such a way as to retard or hasten the attack of an organism. The plant nutrients may act directly on the mechanism, or indirectly and as a modification of the functions of growth in any given habitat". This writer also warned against generalizations as to the effect of nutrition on plant diseases.

Evidence from Colorado and elsewhere indicates that soil fertility is related to losses due to root rot of peas. Harter, Zaumeyer, and Wade (13) reported that "plants that start poorly, as they do on impoverished soils, are much more subject to attack of root rots than plants on rich soils where a good vigorous growth is maintained from the very beginning. This naturally suggests that a fertilizer of the proper proportion of ingredients should be added to the soil where needed." Reinking (29) reported that fertilized fields of New York canning peas gave higher yields than did unfertilized fields when such soils were known to be infested with root rotting organisms. Smith (37) declared that "crop rotation, thorough preparation of the soil, maintenance of fertility, and good drainage help to reduce the damage caused by root rot". By 1939 (8) tests in the San Luis Valley of Colorado had indicated that long rotations, the use of disease-free seed, seed treatment with organic mercurials, and the maintenance of soil fertility reduced losses from root rot diseases. Buchholtz (5) suggested seed treatment with Cuprocide or Semesan and a light sprinkling of phosphate fertilizer in the row with the seed as control measures for root rot and wilt of peas.

Afanasiev and Morris (1) reported that seedling root rot of sugar beets in Montana was controlled by the application of a complete and balanced fertilizer.

Various workers have studied the relation of soil fertility to root rots caused by *Aphanomyces euteiches* Drechs. Investigators at New Jersey Agricultural Experiment Station in a series of reports (12,21,22,23,24) showed that heavy applications of complete fertilizers were effective in reducing the severity of infection. They also found that the nitrogen compounds used in the fertilizer mixture were more influential in reducing root rot than the phosphate and potash components. No benefit resulted when the fertilizer was applied after infection had taken place. Walker (40) and Walker and

Snyder (42) were able to reduce the amount of root rot damage by adding commercial fertilizer to certain Wisconsin soils. They stated that "there is evidence that in some instances, where soils are very lacking in one or more essential nutrients, the weak growth of the plants makes them more susceptible to a variety of soil organisms which do not ordinarily attack vigorous plants."

Walker and Musbach (41) showed that nitrogen additions reduced the root rot damage caused by Aphanomyces euteiches. Smith and Walker (36) showed in 1941 that the severity of Aphanomyces root rot decreased in proportion to the increase of total concentration of the nutrient solution. Varying the ratio of each of the elements N, P, and K from an absence to an excess of each had no effects on disease development.

Studies of the development of pea fusarium wilt, Fusarium oxysporum f. pisi (Lindf.) race 1 S. & H., by Schroeder and Walker (35) demonstrated that with light and temperature conditions favorable to growth of the pea plant an increase in available nutrients results in a suppression of disease development in both resistant and susceptible varieties. Walker and Snyder (42) reported this to be of little benefit.

Following heavy losses a pod pea grower in Colorado sent a sample of soil and pea seed to Dr. J. C. Walker of the Department of Plant Pathology at the

University of Wisconsin. In a written communication to A. M. Binkley, Professor of Horticulture at Colorado State College, Dr. Walker stated that attempts to get the Fusarium root rot and wilt organisms to develop in seedlings grown in this soil were unsuccessful. However, the stand was very poor. Dr. Walker stated that "It occurred to us that this soil might be off balance as far as plant nutrients were concerned. In the next planting we added a small amount of high phosphorus fertilizer to one pot. The next crop showed fine growth of healthy peas in this pot, and again a poor stand in the untreated pot."

This review of the literature indicated that several fertilizers might modify the growth of peas to the extent that losses from root rot might be reduced. Nitrogen applications in excess, such as those which reduced root rot caused by Aphanomyces euteiches, increased hardening of sweet peas. For this reason it was believed that nitrogen applications might favorably affect the stems of pod peas thus offering a mechanical resistance to invasion by the root rotting organisms found in the San Luis Valley. Phosphate increased the succulence of sweet peas, but it was felt that its use might stimulate the root growth so that the plant might survive in spite of infection by F. solani v. martii and other organisms. Potash additions have been shown to increase resistance of cotton to a wilt caused by Fusarium vasinfectum (Atk) (7) and serve as a practical control measure of that disease. The results of other investigators (20,33,34) suggested that an excess of potassium might act to reduce the absorption of calcium by the plant, which may be reflected in thinner cell walls, and a greater susceptibility to death from root rot.

The proper placement of fertilizers for San Luis Valley conditions, where subirrigation methods are used, is unknown. Previous work already mentioned had shown significant differences in plant response resulting from different fertilizers and different types of placement in other areas.

MATERIALS AND METHODS

Peas are grown in the San Luis Valley under conditions which differ from those of other districts in the state and the cultural practices are probably specific for this area. The soil in the area is largely sandy loam in texture and in places contains considerable gravel and cobblestones where the subsoil has been exposed by field leveling. The subsoil at a depth of about two feet consists of stratified water-worn gravels and sandy materials. Often there is enough fine materials present in the topsoil to cause adobe-like aggregates. The total soluble salt concentration of the surface soil is frequently 2000 parts per million, and the average pH is about 8.5 as determined by potentiometric measurements. The San Luis Valley is 7600 feet above sea level, and its normal annual precipitation is approximately eight inches, very little of which falls during the growing season. The water is supplied by subirrigation, which consists of raising the water table within a few feet of the surface.

The peas at Fort Collins were grown under conditions vastly different from those of the San Luis Valley. The soil type was a clay loam of the Fort Collins series with an average of 600 parts per million of total soluble salts and a pH of 7.4. The average annual precipitation is 14.77 inches. Supplemental water is supplied by furrow irrigation. The elevation at Fort Collins is approximately 5000 feet above sea level. The earlier growing season at Fort Collins permitted plantings there three weeks before the plantings in the San Luis Valley.

Field trials were conducted on the San Luis Valley Demonstration Farm near Center, and at Fort Collins. Greenhouse trials using San Luis Valley soil were also conducted at Fort Collins. The fertilizer materials used were ammonium sulfate, 20 per cent available nitrogen; potassium chloride, 60 per cent available K_2O; and superphosphate, 45 per cent P_2O_5. Records were kept of emergence, yield, and the number of living and dead plants at the time of picking. These results were tested for significance by the method of analysis of variance.

All plants after picking in both areas showed blackened lesions on the roots and epicotyl typical of root rot. Laboratory studies by the Plant Pathology Section showed that F. solani v. martii was the organism chiefly responsible for this root rot.

Experimental work conducted in the San Luis Valley

Pod pea variety No. 95, which germinated 86 percent in the laboratory, was treated with Spergon and planted three inches deep with a hand drill set to plant at a uniform rate. The fertilizer was placed by hand at the bottom of a two inch furrow after which the seed was drilled one inch below the fertilizer. The furrows were then filled in. The peas were planted in rows 20 feet long and 34 inches apart.

The land was flooded before planting to remove surface alkali salts and provide sufficient soil moisture for germination. The peas were watered continuously by subirrigation and were furrow irrigated once shortly before the first picking.

The great variability in San Luis Valley soils emphasized the need for replication of fertilizer treatments. In leveling the land to provide an even supply of water through subirrigation, the top soil has been moved into low areas and gravelly to cobbley subsoils have been exposed in other areas. These operations have caused differences in soil fertility, moisture holding capacity, and total soluble salts. These factors have greatly increased the chances of variability between plots and replications. This variability was compensated for in these trials by using five series of randomized blocks in each experiment.

One experiment was designed to determine the effect on the growth of peas of two placements of varying amounts of nitrogen fertilizer combined with constant amounts of phosphate and potassium. The fertilizers were applied to the soil in double rows, one row receiving the fertilizer one inch above the seed, and the other row receiving the same fertilizer approximately two inches to the side and at the same level as the seed. The placement of fertilizer beside the seed was effected by opening a furrow two inches to the side of the row and applying the fertilizer. The treatments consisted of 0-30-4, 5-30-4, 10-30-4, 15-30-4, and 20-30-4 fertilizer combinations, applied at the rate of 200 pounds per acre, and an unfertilized check.

In the second and third experiments, plots receiving increasing amounts of superphosphate (0-10-0, 0-20-0, 0-30-0, 0-40-0) and potash (0-0-10, 0-0-20, 0-0-30, 0-0-40) and unfertilized plots were arranged in two Latin Square designs. The fertilizer was applied above the seed on the single row plots at the rate of 400 pounds per acre.

In the fourth experiment, ten combinations of nitrogen, phosphate, and potassium were applied to the soil at the rate of 100 pounds per acre in randomized blocks, and comparisons of growth were made between fertilized and unfertilized plots. An untreated check and the following fertilizer analyses were used: 0-20-20, 10-20-20, 20-20-20, 20-0-20, 20-10-20, 20-20-0, 20-20-10, 20-0-0, 0-20-0, and 0-0-20.

Experimental work conducted in northern Colorado

The experiment conducted at Fort Collins was similar in design to the fourth experiment on fertilizer combinations in the San Luis Valley. Comparisons of growth were made between the unfertilized plots and the plots receiving different combinations of nitrogen, phosphate, and potassium applied at the rate of 100 pounds per acre and placed two inches to the side and at the same level as the seed. Variety No. 95 treated with Spergon was planted with a hand drill set to plant at a uniform rate of seeding. Each plot consisted of three rows 20 feet long, 34 inches between rows; plots were arranged in five series of randomized blocks.

Greenhouse trials

The effects of fertilizer and seed treatments on stand were studied in the greenhouse, using pod peas grown in field soil from the San Luis Valley. Ten seeds of the variety No. 95 were planted in each four inch pot, paraffined to avoid salt absorption by the pot. The stand of peas was recorded thirty days after planting.

Certain combinations of fertilizer were used in conjunction with seed treatment. These consisted of ammonium sulfate, superphosphate, and potassium chloride, alone and in combination, lime addition, and an unfertilized check. The rate of application was 50 pounds per acre of available nitrogen or potash, and 200 pounds per acre of available phosphate. Lime was added at the rate of 3000 pounds per acre. The seed treatment series consisted of New Improved Ceresan, at the rate of one ounce per bushel of seed, and Spergon, Red Cuprocide, and Arasan at the rate of two ounces per bushel of seed, and an untreated check.

The experiment was designed so that the fertilizer treatments acted as nine replications for the seed treatments, and the seed treatments acted as five replications for the fertilizer treatments. This design enabled a study of the interaction of seed treatment with fertilizer. Two replications of each of the 45 combinations were used.

In another trial the fertilizer treatments consisted of ammonium sulfate added at the rate of 50 pounds per acre of available nitrogen, superphosphate added at the rate of 200 pounds per acre of available P_2O_5, and potassium chloride added at the rate of 50 pounds of available potash per acre. An unfertilized check was also planted.

The fertilizers were added to four series of paraffined pots in which sodium chloride was added in increasing amounts. The total salt content of the untreated soil was 2000 parts per million. The four series of sodium chloride additions consisted of 0,1000,3000 and 5000 parts per million of added salts.

Five replications of each of the sixteen combinations of total salts and fertilizer additions were used.

Ten pea seeds of the Variety No. 95 treated with New Improved Ceresan were planted in the soil in each four inch pot. Stands were recorded ten, twenty, and thirty days after planting.

In the third trial the fertilizer treatments consisted of ammonium sulfate, added at the rate of 25, 50, and 100 pounds of available nitrogen per acre, potassium chloride added at the rate of 25, 50, and

100 pounds per acre of available potash per acre, and superphosphate added at the rate of 100, 200 and 400 pounds per acre. An unfertilized check was also planted.

Ceresan seed treatment was compared with no seed treatment on each fertilizer combination on steamed and unsteamed San Luis Valley soil, making a total of 40 combinations of seed treatment, fertilizer and soils. Two replications of each combination were planted. Stand of peas was recorded six weeks after planting.

RESULTS

Effect of fertilizer on emergence and stand of pod peas in 1938-1942 Colorado trials

Previous work by the Colorado Agricultural Experiment station indicated that soil fertility was related to the problem of pea production in root rot infested soils. In 1938 trials were conducted in the San Luis Valley at Sanford on a subirrigated sandy loam soil. The commercial fertilizers were applied with a grain drill previous to planting. Untreated seed of the variety Improved Strategem was planted May 21, with a grain drill on 1/16 acre plots, using four row plots with no replications. No yield records were taken, but photographs taken at picking time showed no stand from the check plots while the plots receiving fertilizer produced marketable peas.

The results described in Table II are the records made 24 days after planting, and include the mean stand and mean height of plants in two 25 foot row samples.

Table II.--EFFECT OF FERTILIZER TREATMENTS ON STAND, HEIGHT, AND INFECTION WITH ROOT ROT OF IMPROVED STRATEGEM PEAS GROWN AT SANFORD, COLORADO IN 1938.

Fertilizer treatment	Application rate	Mean stand	Mean plant height in inches	Comments
Manure	16 tons/A	42.1	6	
Check	-	45.5	3	Weak growth
Superphosphate	160 lbs./A	55.0	6	
Check	-	55.0	7	
4-12-4	400 lbs./A	88.0	12	Heavy vine growth
Check	-	34.0	6	Root rots killed plants after emergence
20-0-0	400 lbs./A	96.0	12	Heavy foliage. Few root rotted plants.
Check	-	22.0	6	Plants died after emergence.
10-53-0	160 lbs./A	93.0	10	Few root rots.
Check	-	105.0	12	Best check.

Peas were grown in the greenhouse in root rot infested soil from the San Luis Valley during the winter of 1941-42. The stand of peas where lime or seven combinations of nitrogen, phosphate, and potassium were added to the soil was compared with the stand of an untreated check planting. Each fertilizer element was added at the rate of 50 pounds of available nutrient per acre so that a complete fertilizer would total 150 pounds plant food, i.e., 50 pounds each of nitrogen, potassium, and phosphorus. The lime was applied at the rate of 1000 pounds per acre.

The experiment was designed so that the fertilizer treatments acted as replications for five seed treatments being tested, and the seed treatments acted as replications for the fertilizer treatments. Thus each of the four seed treatments (Ceresan, Spergon, Red Cuprocide, Copper Carbonate) and the untreated check were replicated nine times, and each fertilizer treatment was replicated five times. After the stand of peas was recorded, the peas were pulled up to permit a new planting in the same soil. Four such plantings were made. The results are shown in Tables III and IV.

Table III.--EFFECT OF FERTILIZER ADDITIONS AND SEED TREATMENTS AND THEIR INTERACTIONS ON THE STAND OF POD PEAS IN FOUR SUCCESSIVE PLANTINGS IN SAN LUIS VALLEY SOIL IN GREENHOUSE TRIALS DURING THE WINTER OF 1941-42.

Seed treatments	Mean percent of stand									
	Fertilizer Combinations									
	N	P	K	NP	NK	NPK	PK	Lime	Check	Seed treatment mean
Ceresan	87.50	88.75	91.25	86.25	92.50	95.00	80.00	95.00	93.75	90.00
Spergon	45.00	51.25	56.25	50.00	46.25	40.00	46.25	52.50	50.00	46.38
Red Cuprocide	27.50	33.75	30.00	18.75	25.00	28.75	21.25	21.25	33.75	26.67
Copper Carbonate	22.50	33.75	38.75	37.50	16.25	16.25	27.50	25.00	23.75	26.81
Check	13.75	8.75	8.75	5.00	1.25	1.25	1.25	15.00	7.50	6.94
Fertilizer Mean	39.25	43.25	45.00	39.50	36.25	36.25	35.25	41.75	37.75	

Variation due to	Minimum significant difference (5-percent point)
Seed treatment	3.76
Fertilizer	5.00
Each fertilizer with each seed treatment	11.30

Table IV.--EFFECT OF FERTILIZER TREATMENTS ON THE STAND OF POD PEAS IN FOUR SUCCESSIVE PLANTINGS IN SAN LUIS VALLEY SOIL IN GREENHOUSE TRIALS DURING THE WINTER OF 1941-42.

Dates of Planting	Mean percent of stand								
	Fertilizer combinations								
	N	P	K	NP	NK	NPK	PK	Lime	Check
Nov. 29, 1941	81	80	82	66	68	65	68	81	70
Jan. 6, 1942	27	38	36	25	25	27	24	30	27
Feb. 10, 1942	18	18	26	40	27	27	25	24	28
Feb. 18, 1942	27	37	36	27	25	26	24	32	26

Minimum significant difference (5-percent point) 9.94.

Significant interactions between seed treatments, successive plantings, and fertilizers were found in terms of the percentage of peas emerging. Considering only the effects of fertilizer, the application of superphosphate alone and potassium chloride alone to the soil gave a significantly higher stand than that of the unfertilized soil. Ceresan-treated seed gave significantly higher percentage stand on each fertilizer combination than any other seed treatment tested.

In the first planting of November 29, 1941, the stand of pod peas in soil receiving added N, P, K, or lime was significantly higher than the stand in untreated soil or soil receiving added NP, NK, NPK, or PK.

In the second planting in the same soil, January 6, 1942, the stand of peas where P or K was added to the soil was significantly higher than the stand in untreated soil or where N, NP, NK, NPK, or PK was added. The stand where P was added was also significantly greater than the stand in the soil where lime was added.

In the third planting of February 10, 1942, the stand where NP was added to the soil was significantly greater than that of untreated soil or where N, NK, P, K, NPK, PK, or lime was added. The stands in untreated soil and where K, NK, or NPK was added were significantly greater than the stands where N or P were added to the soil.

In the fourth planting of February 18, 1942, the stand of peas where P or K was added was significantly greater than the stand in untreated soil or where N, NP, NPK, or PK was added. The stand where lime was added was also significantly greater than the stand where PK was added.

An interaction was noted between seed treatment and composition of fertilizer.

When no seed treatment was used, the stand of peas where lime or N was added to the soil was significantly greater than that where NPK, PK, or NK was added. When the seeds were treated with Spergon, however, the stand of peas where lime or K was added was significantly greater than the stand where NPK was added. When copper carbonate was used as the seed treatment the stand where NP or K was added was significantly greater than the stand where untreated soil or soil where lime, N, NPK, or NK had been added. When the seed was treated with Cuprocide, the stand of peas on untreated soil and soil where P was added was significantly greater than the stand where lime, PK, or NP was added. When Ceresan was used as a seed treatment, the stand of peas on unfertilized soil and soil where NK, lime, or NPK was added was significantly greater than the stand where PK was added.

This data suggested that the stand response of peas to fertilizer may be modified by the seed treatment used. It is possible that the organic phosphate in Ceresan or the copper in Red Cuprocide provided a stimulus to the plants beyond the protection given from fungus attack, especially in soils deficient in copper or phosphate.

Peas were planted in a series of fertilizer treatments on the San Luis Valley Demonstration Farm near Center in the spring of 1942. The stand of peas on unfertilized check plots and plots where ten combinations of nitrogen, phosphate, and potassium were applied to soil were compared on five replicated series. The soil was comparatively dry at planting time. The fertilizer was applied one inch below the seed at the rate of 200 pounds per acre. Stand counts were made, but no yield records were obtained.

A second experiment was conducted to study the effects of increasing amounts of phosphate on the stand of peas, when constant amounts of nitrogen and potassium were included in the fertilizer combination. The fertilizer was applied one inch below the seed at the rate of 200 pounds per acre.

The results tabulated in Tables V and VI indicated that the stand of pod peas was significantly affected by fertilizer applications. Fertilizer plots without added nitrogen had a significantly greater number of peas

Table V.--EFFECT OF CERTAIN FERTILIZER APPLICATIONS PLACED BELOW THE SEED AT RATE OF 200 POUNDS PER ACRE ON STAND OF POD PEAS IN THE SAN LUIS VALLEY IN 1942.

Fertilizer analysis	Mean stand 42 days after planting	Mean stand 84 days after planting				Mean percentage dead calculated on total emergence
		Total	Living	Dead	Percentage dead	
0-0-20	111.4	108.6	92.6	16.0	14.98	21.08
0-20-20	108.4	108.4	92.0	16.4	14.88	25.58
0-20-0	97.4	91.6	78.2	13.4	14.70	26.22
0-0-0	92.2	89.8	71.6	18.2	19.98	34.86
20-0-20	87.0	83.6	68.0	15.6	19.08	31.48
10-20-20	76.8	75.6	66.6	9.0	12.10	19.38
20-0-0	66.0	56.4	45.6	10.8	20.26	37.00
20-20-0	53.8	56.2	45.6	10.6	18.72	23.58
20-20-20	55.2	47.4	36.6	10.8	25.34	39.48
20-10-20	48.8	43.8	37.0	6.8	10.90	34.46
20-20-10	48.8	43.2	37.2	6.0	13.72	28.78
Minimum significant difference (5-percent point)	23.28	27.04	24.98	9.92	9.32	14.20

Table VI.--EFFECT OF INCREASED AMOUNTS OF PHOSPHATE IN FERTILIZER COMBINATIONS APPLIED BELOW THE SEED AT THE RATE OF 200 POUNDS PER ACRE ON THE STAND OF POD PEAS IN THE SAN LUIS VALLEY IN 1942.

Fertilizer analysis	Mean stand 42 days after planting	Mean stand 84 days after planting
10-0-10	88.4	106.4
10-10-10	94.6	98.4
10-20-10	88.8	90.6
10-30-10	95.8	100.6
10-40-10	86.2	89.6
10-50-10	99.8	108.4
10-60-10	98.4	97.0
0-0-0(check)	120.4	134.2
Minimum significant difference (5-percent point)	31.74	34.47

emerging and more living plants at the end of the picking season than did the plots receiving nitrogen additions. Plots receiving small amounts of nitrogen had significantly more peas emerging and more living plants at the end of the picking season than did the plots receiving larger amounts of nitrogen.

Plots receiving no nitrogen, but receiving potassium and phosphate, alone or in combination, produced higher stands, but not significantly so, than did the unfertilized check plot. The plots receiving a complete fertilizer (20-20-20) showed significantly higher percentage of dead plants than six other treatments, and a higher percentage of dead plants compared to total emergence than plots receiving 10-20-20, 0-0-20, and 20-20-0 fertilizers. The percentage of dead plants compared to the total plants emerging in the plots receiving nitrogen alone was significantly higher than in the plots receiving potash alone or a 10-20-20 combination. The untreated plot and 20-10-20 plots also had a significantly higher percentage of loss than the plots where 10-20-20 was added.

The unfertilized plots had higher numbers of plants than plots where increasing amounts of phosphate combined with constant amounts of nitrogen and potassium were applied. There were no significant differences in stand between treatments where increasing amounts of phosphate combined with constant amounts of nitrogen and potassium were applied.

The results showed that ammonium sulfate placed in the soil under the seed at planting time reduced emergence and increased the percentage of dead plants. Since previous work by other investigators has shown that placement of fertilizers below the seed, especially fertilizers containing inorganic nitrogen, reduced emergence, the injury to stand from ammonium sulfate may have been due to improper placement of the fertilizer. Dryness of the soil at planting time would tend to emphasize such injury, since injury from fertilizers is increased in comparatively dry soils.

The results of these preliminary trials in the greenhouse and in the San Luis Valley indicated that the stand of peas in the San Luis Valley area was affected, not only by seed treatment, but by the application of fertilizers to the soil. The purpose of the 1943 experiments was to determine which fertilizers, alone or in combination, would increase the number of peas emerging, the number of living peas at picking time, and the yield.

Effect of fertilizers on emergence, yield, and number of living plants in 1943 studies

San Luis Valley trials in 1943

The effect of increasing amounts of nitrogen, with phosphate and potash constant, applied above or to the side of the seed on the stand of peas is summarized in Table VII and shown graphically in Figure I.

The placement of fertilizer had a noticeable effect on the stand of pod peas. Where the fertilizer was placed two inches to the side and at the level of the seed at planting time, the stand was significantly higher in three of the four counts than the stand of peas in the plots where the fertilizer was placed one inch above the seed. The effect of placement beside the seed was most apparent when complete fertilizers containing high amounts of nitrogen were added to the soil. In all counts, the stand of peas where 15-30-4 was added to the soil beside the seed was significantly higher than the stand when the same fertilizer was placed above the seed. Except for the stand count made on August 18, the same result was true for the 20-30-4 fertilizer. The check planting, which received no fertilizer, showed higher stand in the series receiving fertilizer beside the seed than in the series where the fertilizer was placed above the seed in the counts of total stand made on June 8 and August 7. The use of a wheel hoe to cut a shallow furrow for fertilizer placement to the side of the seed tended to throw more loose dirt on top of the

Table VII.--EFFECT OF INCREASING AMOUNTS OF NITROGEN, WITH PHOSPHATE AND POTASH CONSTANT, APPLIED ABOVE OR TO THE SIDE OF THE SEED, ON THE STAND OF POD PEAS IN THE SAN LUIS VALLEY IN 1943.

Fertilizer analysis	Mean stand June 8			Mean stand August 7			Mean stand of living peas August 7			Mean stand of living peas August 18		
	Placement			Placement			Placement			Placement		
	above seed	beside seed	fertilizer mean	above seed	beside seed	fertilizer mean	above seed	beside seed	fertilizer mean	above seed	beside seed	fertilizer mean
0-0-0 (check)	32.4	41.2	36.8	27.4	34.2	30.8	15.4	16.0	15.7	5.6	5.8	5.7
0-30-4	37.6	35.0	36.3	33.0	29.4	31.2	22.0	20.2	21.1	6.8	8.2	7.5
5-30-4	32.2	32.2	32.2	27.6	27.8	27.7	14.2	13.2	13.7	3.2	4.2	3.7
10-30-4	30.6	35.4	33.0	26.2	29.0	27.6	14.4	17.0	15.7	3.8	5.6	4.7
15-30-4	23.4	32.8	28.1	20.0	29.2	24.6	8.4	17.4	12.9	3.0	7.2	5.1
20-30-4	21.8	34.0	27.9	18.2	28.8	23.5	5.6	13.6	9.6	1.0	3.8	2.4
Placement mean	29.67	35.1		25.4	29.7		13.3	16.2		3.9	5.8	

Variation due to	Minimum significant difference (5-percent point)			
	Total plants June 8	Total plants August 7	Living plants August 7	Living plants August 18
Placement	2.70	2.3	3.01	1.42
Fertilizer	4.96	4.1	4.06	2.44
Each fertilizer with each placement	7.01	5.8	5.75	3.45

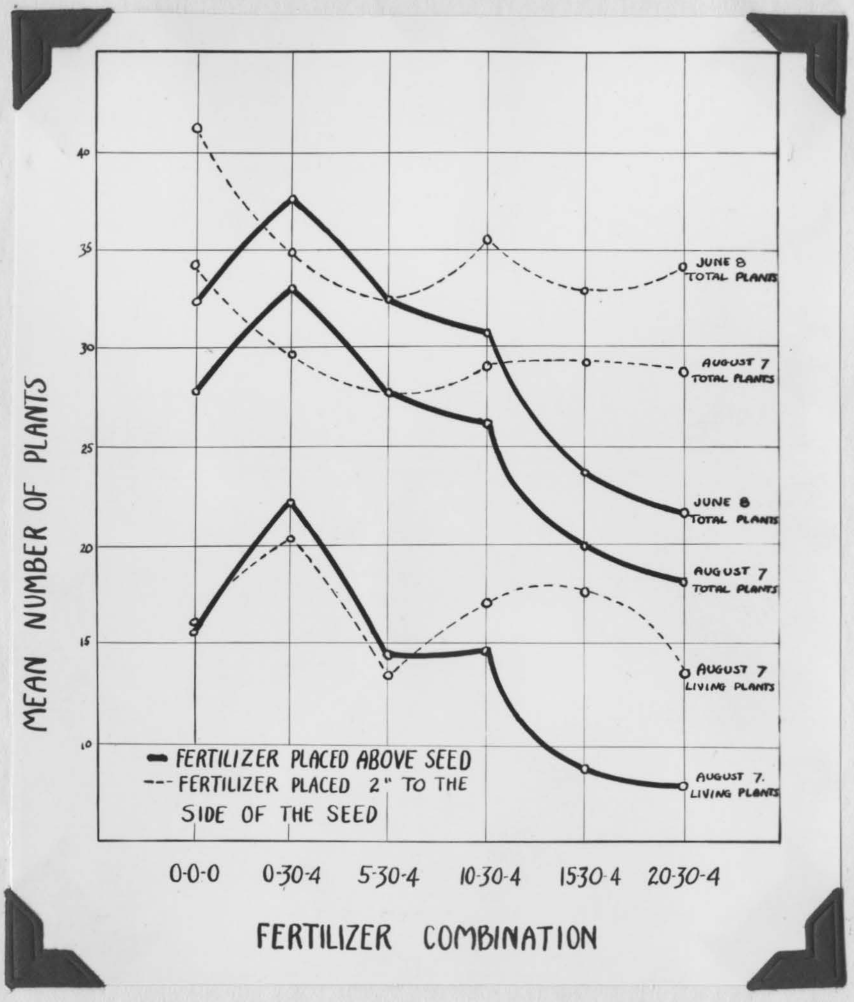

FIGURE 1.--Effect of increasing amounts of nitrogen, with phosphate and potash constant, applied above or to the side of the seed, on the stand of pod peas in the San Luis Valley in 1943.

seed, which probably gave the seed a better chance to germinate in the rows where side placement of the fertilizer was practiced. This difference disappeared by August 7 when the counts of living peas were taken. There was no significant difference in the yields from the two check plots.

The plot which received a 0-30-4 fertilizer showed significant increases in the number of living plants at the time of first picking compared to the other five plots where no fertilizer or increasing amounts of nitrogen combined with 0-30-4 was added.

The stand of peas in these plots was affected by the placement of fertilizer. When the fertilizer was placed above the seed, the stand of peas decreased as the amount of nitrogen combined with 0-30-4 increased. When the fertilizer was placed two inches to the side of the seed, the stand of peas did not decrease in proportion to the increase in the amount of nitrogen. Some of the plots where the amount of nitrogen added was increased showed higher stands of living peas at picking time than the unfertilized check.

These results indicated that applications to the side of the seed reduced injury to stand caused by nitrogen carriers in the fertilizer.

The differences in yield of the first picking, August 7, (Table VIII) reflected the difference in

Table VIII.--EFFECT OF INCREASING AMOUNTS OF NITROGEN, WITH PHOSPHATE AND POTASH CONSTANT, APPLIED ABOVE OR TO THE SIDE OF THE SEED, ON THE YIELD OF POD PEAS IN THE SAN LUIS VALLEY IN 1943.

Fertilizer analysis	Mean yield in ounces					
	August 7 First picking			August 18 Second picking		
	Fertilizer placement			Fertilizer placement		
	above seed	beside seed	ferti-lizer mean	above seed	beside seed	ferti-lizer mean
0-0-0 (check)	52.2	49.8	51.0	5.2	5.6	5.4
0-30-4	77.6	68.0	72.8	8.0	9.2	8.6
5-30-4	56.6	48.0	52.3	4.4	4.2	4.3
10-30-4	50.2	61.2	55.7	6.0	7.4	6.7
15-30-4	34.2	53.0	43.6	6.6	9.4	8.0
20-30-4	28.2	53.4	40.8	2.4	5.8	4.1
Placement mean	49.83	55.57		5.4	6.7	

Variation due to	Minimum significant difference (5-percent point)	
	August 7	August 18
Placement	14.80	3.49
Fertilizers	12.97	2.99
Each fertilizer with each placement	18.34	4.23

stand, especially the differences in stand of living peas on the same date. The heaviest yields from both fertilizer placements came from the plots where 0-30-4 was added, where the average yield was significantly greater than the yield from the unfertilized check plot or the plots where increasing amounts of nitrogen were added to 0-30-4.

As the placement of fertilizers containing nitrogen affected stand, it also affected yield. When the fertilizer was placed above the seed, the addition of increasing amounts of nitrogen in combination with 0-30-4 resulted in successive decreases in yield. When a similar series of fertilizers was added two inches to the side of the seed, the yield did not decrease in proportion to the increase in nitrogen. In fact, when the fertilizer was placed beside the seed the plots where 10-30-4 was added had higher yields than the unfertilized check plots but lower yields than where 0-30-4 was added.

The second picking was probably not heavy enough to be of commercial importance, but the average yield from the plots where 0-30-4 was added was heavier than the average yield from plots where increasing amounts of nitrogen were added. When the fertilizer was applied above the seed, or to the side of the seed, the yield from the 10-30-4 and 15-30-4 plots was higher than the yield from the 5-30-4 and 20-30-4 plots and the unfertilized check plots. The graphic representation of these results is presented in Figure II.

Since the fifth replication was located next to a grain field which competed with the peas for moisture, this replication was omitted in the calculation of the values in Table IX. There were significant losses in stand from the addition of phosphate above the seed, but yield increased when increased amounts of phosphate were applied. These results are shown graphically in Figure III.

The effects of potash additions are shown in Table X and are described graphically in Figure IV. The addition of small amounts of potash applied above the seed resulted in a slight increase in stand, while the addition of greater amounts of potash resulted in decreases in stand. While there were no significant differences in yield, the plot with the poorest stand, 0-0-30, had the poorest yield.

The effect on stand and yield of nitrogen, phosphate, and potassium additions, alone and combined, is shown in Table XI.

None of the plots where fertilizers were added had stands significantly greater than the stand of the unfertilized check, although the number of peas in the 0-20-0 plots was higher than the check in all four stand counts. The number of living plants on August 7 and 18

Table IX.--EFFECT OF INCREASING AMOUNTS OF PHOSPHATE ON THE STAND AND YIELD OF POD PEAS GROWN IN THE SAN LUIS VALLEY IN 1943.

Fertilizer analysis 1/	Mean stand				Mean yield
	Emergence June 9	Total stand August 7	Living August 7	Living August 18	In ounces August 7
Check	58.75	49.50	31.00	14.25	67.75
0-10-0	54.25	48.25	34.00	13.75	82.00
0-20-0	53.75	47.25	30.50	10.00	80.75
0-30-0	54.75	48.75	30.00	12.75	91.50
0-40-0	46.75	40.50	28.50	11.25	91.25
Minimum significant difference (5-percent point)	10.63	9.00	7.99	5.80	47.99

1/ The application of these fertilizers at the rate of 400 pounds per acre meant that the 0-10-0 plot received 40 pounds of available phosphate per acres, the 0-20-0 plot received 80 pounds, the 0-30-0 plot received 120 pounds, and the 0-40-0 plot received 160 pounds of available phosphate per acre.

Table X.--EFFECT OF INCREASING AMOUNTS OF POTASH ON THE STAND AND YIELD OF POD PEAS GROWN IN THE SAN LUIS VALLEY IN 1943.

Fertilizer analysis 1/	Mean stand				Mean yield
	Emergence June 9	Total August 7	Living August 7	Living August 18	in ounces August 7
Check	49.4	42.8	25.4	11.2	50.8
0-0-10	52.4	44.4	28.8	14.6	50.4
0-0-20	39.8	35.8	21.2	11.4	52.8
0-0-30	40.6	36.6	15.8	7.4	33.0
0-0-40	48.0	38.4	18.4	9.4	50.0
Minimum significant difference (5-percent point)	9.61	8.09	9.90	6.85	28.43

1/ The application of these fertilizers at the rate of 400 pounds per acre meant that the 0-0-10 plot received 40 pounds of available potash per acre, the 0-0-20 plot received 80 pounds, the 0-0-30 plot received 120 pounds and the 0-0-40 plot received 160 pounds of available potash per acre.

Table XI.--EFFECTS OF NITROGEN, PHOSPHATE, AND POTASSIUM, ALONE AND COMBINED, ON STAND AND YIELD OF POD PEAS GROWN IN THE SAN LUIS VALLEY IN 1943.

Fertilizer analysis	Mean stand				Mean yield in ounces	
	Emergence June 8	Total plants August 7	Living plants August 7	Living plants August 18	August 4	August 18
0-20-20	91.4	70.8	44.0	15.0	161.0	21.8
10-20-20	87.0	74.8	46.0	16.0	158.4	21.0
20-20-20	98.6	79.6	46.8	14.4	148.8	20.2
20-0-20	80.6	61.0	19.6	4.2	73.8	12.2
20-10-20	88.6	71.0	46.2	13.6	158.8	14.8
20-20-0	88.4	73.2	46.0	13.0	153.4	22.0
20-20-10	105.8	90.2	58.2	15.2	204.6	21.2
20-0-0	100.2	83.6	61.0	20.2	206.4	23.6
0-20-0	111.0	94.4	66.2	20.8	184.8	19.2
0-0-20	99.2	80.0	48.8	14.4	149.8	16.0
0-0-0 (check)	106.0	91.2	56.0	16.0	168.8	17.8
Minimum significant difference (5-percent point)	15.85	12.55	27.36	15.70	108.72	21.58

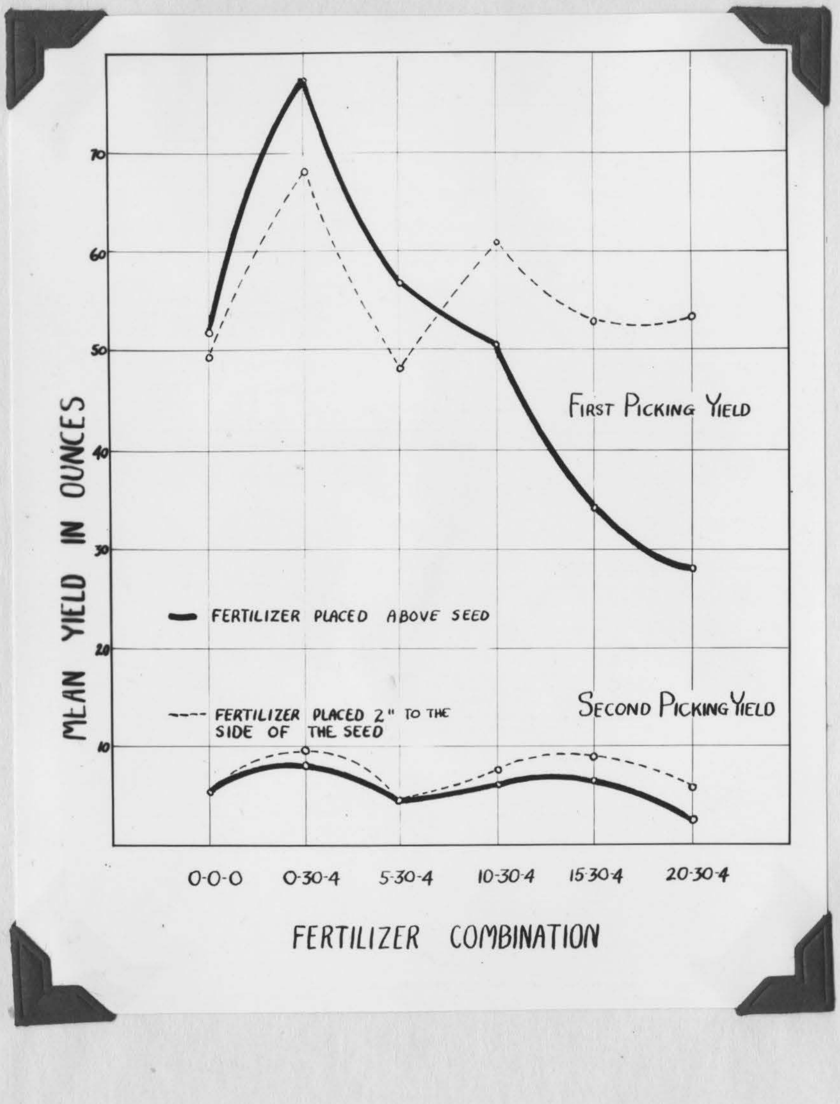

FIGURE 2.--Effect of increasing amounts of nitrogen, with phosphate and potash constant, applied above or to the side of the seed, on the yield of pod peas in the San Luis Valley in 1943.

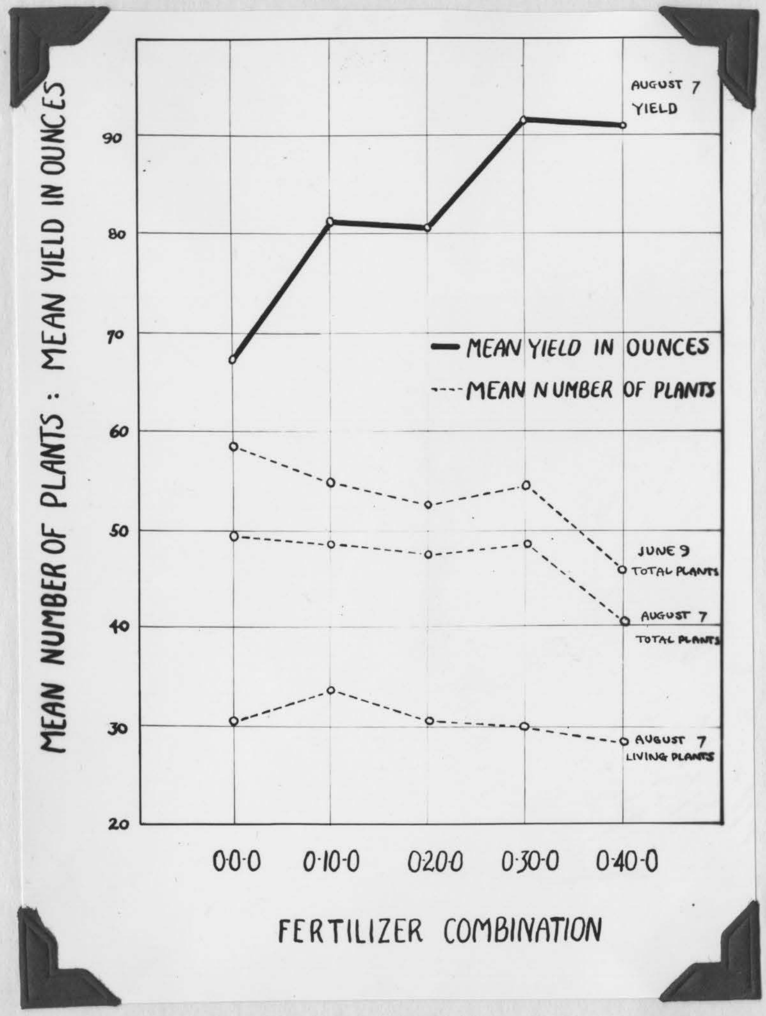

FIGURE 3.--Effect of increasing amounts of phosphate on the stand and yield of pod peas grown in the San Luis Valley in 1943.

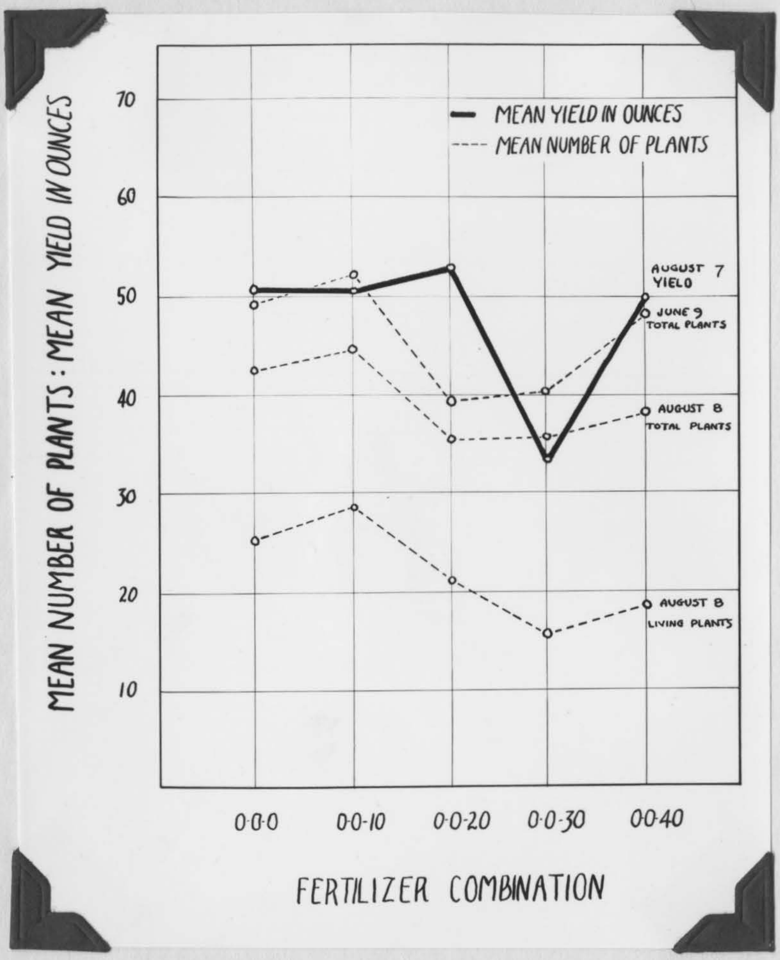

FIGURE 4.--Effect of increasing amounts of potash on the stand and yield of pod peas grown in the San Luis Valley in 1943.

in the plots where 20-0-0 or 20-20-10 was added was higher than the check planting, while none of the fertilizers significantly increased stands over the control.

As shown in Figure V, the fertilizer analysis significantly affected the stand of peas. A combination of nitrogen and potash (20-0-20) had the fewest plants in all four stand counts. The inclusion of phosphate in the ratio (20-10-20 and 20-20-20) more than doubled the number of living plants on August 7 and more than tripled the number of living plants on August 18, compared to the stand of peas in the 20-0-20 plots.

In the first picking the plots which received ammonium sulfate alone, superphosphate alone, or the 20-20-10 combination yielded more than the unfertilized check and yielded significantly more than the plot where a combination of nitrogen and potash was added. The second picking was probably not heavy enough to be of commercial importance.

In general, when the number of plants alive at picking time exceeded the stand of the check plot, the yield was greater than the yield of the check. The five exceptions to this observation in the second picking (20-20-0, 20-20-20, 10-20-20, 20-20-10, and the 0-20-20 plots) contained 20 units of phosphate in the fertilizer combination. These exceptions had fewer living plants and higher yields than the check on August 18.

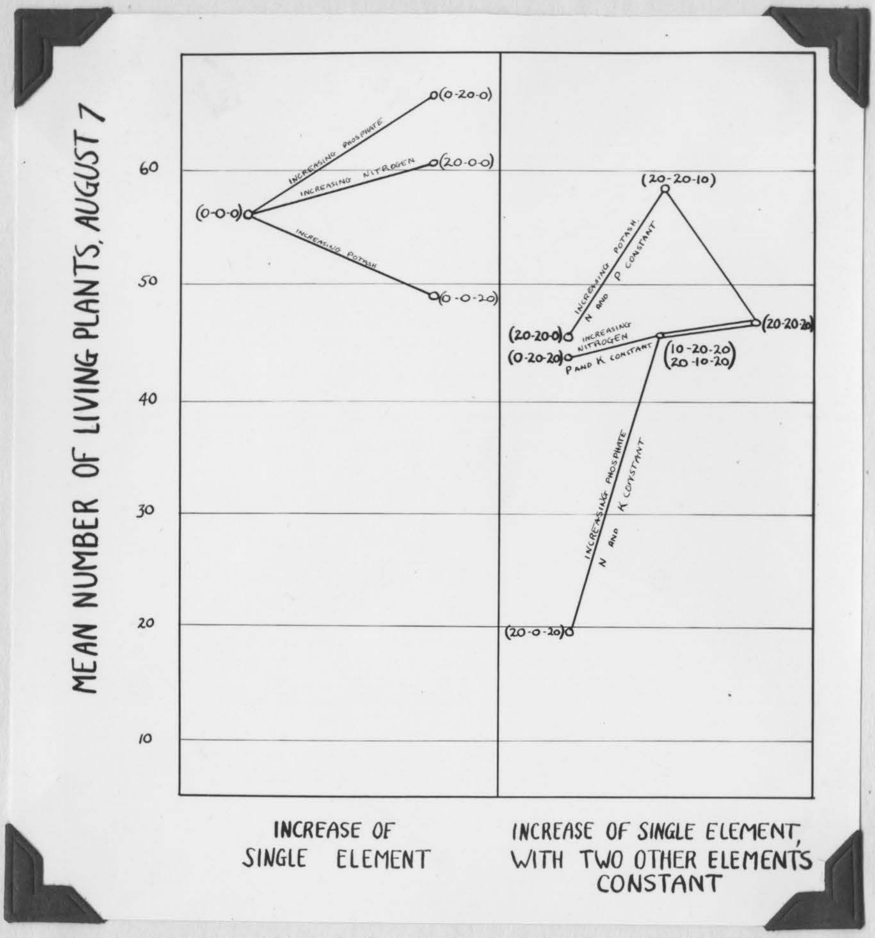

FIGURE 5.--Effect of nitrogen, phosphate, and potassium alone or in combination, on the stand of living peas grown in the San Luis Valley in 1943.

In the picking of August 4, the only one of commercial importance, there was great variation in the yield response where different fertilizer combinations had been added to the soil. While most of the yield differences were not significant, certain trends were evident. These trends are shown graphically in Figure VI.

The addition of nitrogen alone or phosphate alone increased the yield as compared to the check, but a combination of nitrogen and phosphate yielded more than the check only if the fertilizer combination included ten units of potassium. If potassium was absent or 20 units of potassium were included with the nitrogen and phosphate combination, the yield was below that of the check. The addition of potassium alone decreased the yield. The necessity of including phosphate in a complete fertilizer was shown by the poor yields where a combination of nitrogen and potash was added, and the comparatively better yields where ten or 20 units of phosphate were included in the fertilizer combination.

Northern Colorado trials
in 1943

At Fort Collins, the addition of fertilizer beside the seed in general increased the stand and yield of peas, compared to the check. While the addition of nitrogen alone, phosphate alone or potash alone tended

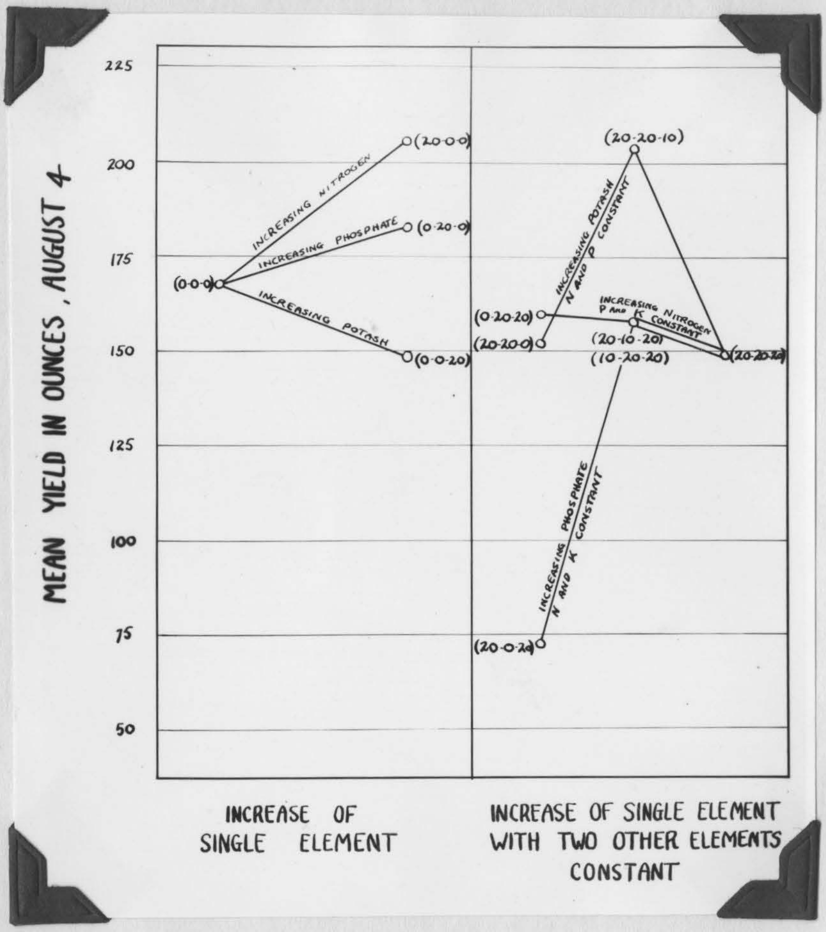

FIGURE 6.--Effects of nitrogen, phosphate, and potassium, alone or in combination, on the yield of pod peas grown in the San Luis Valley in 1943.

to increase the stand and yield, the greatest increases were obtained when combinations of these fertilizers were used. A combination of phosphate and potash produced the highest number of plants in all four stand counts but did not result in the highest yield in either picking. The four highest average yields of both pickings came from fertilizer plots where the fertilizer contained both nitrogen and potash. Three of the four highest yielding plots received phosphate in addition to the nitrogen and potash. The combination of nitrogen and potash (20-0-20) resulted in significantly more dead plants than where phosphate was included in the combination (20-10-20).

The importance of potash was indicated by the significantly higher yields in the second picking from the 0-0-20 plots and 10-20-20 plots compared to the yield where 20-20-0 had been added. When the average yield per picking is considered, the plots where nitrogen was added yielded more peas than where no nitrogen was added.

These results at Fort Collins (Table XII) indicated that complete fertilizers gave the best yields, with the nitrogen component being essential for increased total yields, the phosphate delaying the death of plants, and the potash maintaining yields in the second picking.

Table XII.--EFFECT OF NITROGEN, PHOSPHATE, AND POTASSIUM, ALONE OR COMBINED, ON STAND AND YIELD OF POD PEAS GROWN IN NORTHERN COLORADO IN 1943.

Fertilizer analysis	Mean stand three rowplot		Mean stand middle row July 21, 1943			Mean yield in ounces of middle row		
	13 days after planting	35 days after planting	Living	Dead	Total	July 12	July 20	Mean
0-20-20	218.8	242.2	61.6	16.4	78.0	50.6	33.0	41.8
10-20-20	203.0	230.6	57.8	18.8	76.6	50.2	42.0	46.1
20-20-20	203.6	231.4	54.6	16.6	71.2	54.2	36.0	45.1
20-0-20	198.0	225.8	50.4	19.8	70.2	60.4	35.0	47.7
20-10-20	214.0	230.0	58.0	14.6	72.6	62.8	37.8	50.3
20-20-0	202.6	226.6	56.0	17.0	73.0	61.8	25.6	43.7
20-20-10	211.2	236.2	56.0	18.6	74.6	53.6	32.0	42.8
20-0-0	194.2	224.4	53.2	16.8	70.0	46.8	40.0	43.4
0-20-0	198.4	218.0	50.8	15.8	66.6	46.6	30.2	38.4
0-0-20	208.6	234.2	51.6	15.6	67.2	39.4	42.6	41.0
0-0-0	186.4	226.2	48.6	15.0	63.6	41.0	33.8	37.4
Minimum significant difference (5-percent point)	13.81	13.81	13.72	5.18	10.27	15.48	15.48	10.945

Significant differences in stand appeared from the interaction of fertilizer additions to the soil and seed treatments on peas planted in San Luis Valley soil in the greenhouse. These results are tabulated in Table XIII. The additions of certain fertilizers significantly reduced stands compared to the underti-lized check when Spergon or Arasan were used. When Ceresan or Cuprocide seed treatments were used, no significant differences in stand appeared between ferti-lized and unfertilized soils.

Figure VII demonstrates that seed treatment was necessary for emergence of peas in unfertilized soils, while Figure VIII shows that the application of a com-bination of nitrogen and potash reduced significantly the stand of peas grown from Spergon-treated seed. Figures VIII and IX indicate that the application of fertilizers to the soil did not reduce the stand of plants grown from Ceresan-treated seed.

In both the field trials in the San Luis Valley and the greenhouse trials using field soil from the San Luis Valley, the poorest stand of Spergon-treated peas occurred where a combination of nitrogen and potash was added to the soil. In the San Luis Valley, the addition of one combination of phosphate-potash resulted in significantly more peas emerging, signi-ficantly more live peas at picking time, and significantly heavier yields compared to the unfertilized check. In the greenhouse trials, the addition of a combination of phosphate and potassium resulted in more plants than the unfertilized check with each seed treatment.

Greenhouse trials in 1943

Table XIII.--EFFECT OF FERTILIZER ADDITIONS AND SEED TREATMENTS, AND THEIR INTERACTION ON THE STAND OF POD PEAS GROWN ON SAN LUIS VALLEY SOIL IN THE GREENHOUSE IN 1943

Fertilizer	Mean stand thirty days after planting				
	Seed treatment				
	Ceresan	Spergon	Cuprocide	Arasan	Check
N	9.5	2.0	6.5	2.0	.5
P	9.5	3.0	6.0	3.0	.5
K	7.0	3.0	5.0	6.0	.5
NP	9.5	3.5	6.5	4.5	.0
NK	9.0	1.5	3.5	7.0	1.5
NPK	7.0	3.5	7.5	4.5	.0
PK	10.0	7.5	7.0	9.0	.5
Lime	9.0	4.0	5.5	9.5	.0
Check	9.0	7.0	5.5	8.0	1.0

Minimum significant difference (5-percent point)
for all seed treatments with each fertilizer 3.1

for seed treatments (excluding the check) with each fertilizer 3.7

FIGURE 7.--Effect of seed treatments on the stand of pod peas grown on unfertilized San Luis Valley soil in the greenhouse in 1943. The four seed treatments, reading from left to right, were New Improved Ceresan, Spergon, Cuprocide, and Arasan. The pair of pots on the extreme right were planted with untreated seed.

FIGURE 8.--Effect of seed treatments on the stand of pod peas grown in the greenhouse on San Luis Valley soil where a combination of nitrogen and potash fertilizer had been added to the soil. The seed treatments used, reading from left to right, were Ceresan, Spergon, Cuprocide, and Arasan. The fifth pair of pots were planted with untreated seed.

FIGURE 9.--The effect of fertilizer additions on the stand of pod peas grown from Ceresan-treated seed planted in fertilized and unfertilized soil from the San Luis Valley in 1943 greenhouse trials. The fertilizer additions to the soil, reading from left to right, consisted of NPK, PK, N, no fertilizer, K, P, NP, and NK.

As total salts increased, there was a delay in emergence. Most of this difference disappeared after 30 days. The addition of fertilizer tended to delay emergence, but this difference disappeared for the most part after 30 days. A slight increase in emergence 20 and 30 days after planting resulted from the addition of 1000 parts per million of sodium chloride. These results are summarized in Table XIV.

Table XIV.--EFFECT OF SODIUM CHLORIDE AND FERTILIZER ADDITIONS TO SAN LUIS VALLEY SOIL ON THE EMERGENCE OF POD PEAS GROWN IN 1943 GREENHOUSE TRIALS.

Parts per million of sodium chloride additions	Fertilizer treatment	Mean stand		
		Days after planting		
		10	20	30
0	0	4.2	8.2	8.8
0	N	3.6	8.2	8.8
0	P	2.6	9.0	9.0
0	K	4.6	8.8	9.2
1000	0	3.6	9.4	9.8
1000	N	2.8	8.6	9.2
1000	P	2.6	9.2	9.2
1000	K	2.2	8.4	9.0
3000	0	3.4	9.0	9.6
3000	N	3.0	7.8	8.8
3000	P	1.6	8.2	8.6
3000	K	.8	8.6	8.8
5000	0	.6	6.8	7.8
5000	N	.4	7.8	8.8
5000	P	1.0	6.8	7.8
5000	K	.6	7.4	8.2
Minimum significant difference (5-percent point)		2.04	2.04	2.04

The results described in Table XV indicate that as the amount of sodium chloride in the soil increased, the number of living peas decreased, irrespective of fertilizer additions.

In addition the peas grown in soils of high salt content showed fewer nodules, less root growth, shorter vine growth, and more root discoloration than did peas grown in soil where no sodium chloride was added.

These results indicate that these fertilizers had little value in the reduction of losses of stand on soils with a high salt content.

Table XV.--EFFECT OF SODIUM CHLORIDE AND FERTILIZER ADDITIONS TO SAN LUIS VALLEY SOIL ON THE STAND OF LIVING, UNGIRDLED[1] PLANTS EIGHT WEEKS AFTER PLANTING IN THE 1943 GREENHOUSE TRIALS.

Parts per million of added sodium chloride	Mean stand of pea plants			
	Fertilizer additions			
	Check	Nitrogen	Phosphate	Potash
0	8.0	9.0	8.6	9.0
1000	9.6	7.4	8.6	7.8
3000	6.4	5.2	5.6	5.0
5000	2.2	5.2	2.0	2.0

Minimum significant difference (5-percent point) is 2.4

1/ Many plants were completely girdled at the stem or root by the action of root rotting organisms or high total salts. Since such plants would soon die, they were not counted as living plants in this table. Plants with no lesions or minor root rot lesions were counted as living plants.

The results summarized in Table XVI indicate that the organisms causing root rot were primarily soil-borne and were assumed to be completely destroyed by steaming the soil. Organisms borne on the surface of the seed were comparatively unimportant in this test. While only a few plants emerged in unsteamed soil where no seed treatment was used, 85 percent of the seedlings emerged in unsteamed soil when Ceresan seed treatment was used. Certain fertilizer additions to the soil had no significant effect in reducing stand losses from root rot in the six week period of this test .

Steaming the soil and the use of seed treatment affected not only stand, but the percentage of peas showing lesions caused by root rot. Peas grown from Ceresan-treated seed planted in steamed soil showed no lesions, while approximately two percent of the peas grown from untreated seed planted in steamed soil showed lesions. Twenty-five percent of the peas grown from Ceresan-treated seed planted in unsteamed soil showed lesions, while peas grown from untreated seed in unsteamed soil showed 50 percent of the plants girdled by root rot, an additional forty-five percent had lesions, and only five percent of the plants showed no lesions.

Table XVI.--EFFECTS OF CERESAN SEED TREATMENT, STEAM STERILIZATION OF THE SOIL, AND INCREASING AMOUNTS OF NITROGEN, PHOSPHATE OR POTASH ON THE STAND OF LIVING PEAS SIX WEEKS AFTER PLANTING IN SAN LUIS VALLEY SOIL IN 1943 GREENHOUSE TRIALS.

Rate of fertilizer addition per acre	Mean stand of peas living and not girdled			
	Steamed soil		Unsteamed soil	
	Ceresan seed treatment	No seed treatment	Ceresan seed treatment	No seed treatment
Unfertilized control	9.5	9.0	9.5	.0
25 pounds nitrogen	9.0	8.5	9.5	.5
50 " "	9.5	8.5	8.0	.0
100 " "	9.5	9.5	8.0	1.0
100 " phosphate	8.0	8.5	7.5	2.0
200 " "	10.0	8.0	9.5	.5
400 " "	9.5	8.5	9.0	.5
25 " potash	9.5	9.5	8.0	.5
50 " "	9.5	8.5	8.0	.0
100 " "	9.5	10.0	8.0	.0

Minimum significant difference (5-percent point) between each fertilizer treatment and each combination of soil and seed treatment, except the combination of no seed treatment with unsteamed soil, is 2.39.

DISCUSSION

Effect of ammonium sulfate additions to the soil

The effect of ammonium sulfate additions to the soil has been modified by soil moisture at planting time and by placement of the fertilizer. In 1942 the soil was comparatively dry at planting time, and the placement of ammonium sulfate one inch beneath the seed significantly reduced the stand of peas. In 1943 trials where the ammonium sulfate was placed above the seed, as in the San Luis Valley, or two inches to the side of the seed, as at Fort Collins, the stand at picking time and yield of these plots were higher than those of the unfertilized check planting. The mixing of ammonium sulfate with the soil also resulted in stand increases in the preliminary trial of 1938.

Peas, while legumes that produce nitrogen in the root nodules, also utilize soil nitrogen. The cool soil temperatures at the time of planting may mean that less nitrogen in the soil is available to the plant. The addition of ammonium sulfate then may result in more vigorous plants. This vigor may result in a plant more tolerant to root rots or the root growth is more rapid and new root growth or rapid root replacement may be a factor and thus produce a higher yielding plant. Such an explanation must assume that the ammonium sulfate is applied in such a way as to avoid plasmolysis of the sprouting seed and injury to the plants.

Effect of phosphate additions to the soil

Phosphate additions have also shown variable results. Walker in 1931 was able to increase the stand of peas in greenhouse experiments by adding small amounts of high phosphate fertilizer. Preliminary experiments in 1938 with additions of superphosphate failed to show increases in stand, but that may have been due to the lack of replications and the variability of the check plantings. In the greenhouse trials of 1941-42, the addition of phosphate significantly increased stand compared to the check. In the 1942 field trials in the San Luis Valley, the plots where phosphate was added had higher stand than the check, but not significantly so. In the 1943 trials, the application of increasing amounts of treble superphosphate above the seed resulted in slight decreases in stand, with the greatest decrease coming with the heaviest application of superphosphate. However, yield increased as the amount of superphosphate added increased.

In the fertilizer ratio studies, the plots where superphosphate was added showed increased stand and yield compared to the check. Since there was less soil moisture at time of planting in the plots where increasing amounts of superphosphate were added, compared to the fertilizer ratio plots, the results indicate that the emergence of peas in phosphated plots was also affected by soil moisture. The greatest injury from phosphate additions occurred in the drier soils. The high pH and high lime content of San Luis Valley soils tends to reduce the availability of phosphate, and as a result the addition of phosphate provided a supply when the amount already present in the soil was inadequate. Phosphate, which tends to increase root development and hasten maturity, perhaps gives the plant a better chance to survive in root rot infested soils and produce increased yields.

<u>Effect of potassium additions to the soil</u>

The variability of plant response to potassium additions may be due to the different amounts applied. The 1943 trials in the San Luis Valley indicated that small amounts alone or combined (0-0-10 or 20-20-10) may increase stand and yield while an excess (0-0-20, 0-0-30, 0-0-40, 20-20-20) may reduce stand and yield. A small amount stimulated growth, while an excess caused injury to the plant. Carolus (6) has reported that potassium in large amounts depressed the absorption of nitrogen by lima beans. Excess amounts of potassium may thus interfere with the normal growth of the plant.

Effect of fertilizer combinations in the San Luis Valley

One combination of nitrogen, phosphate, and potassium (20-20-10) resulted in higher stand and yields than the check in the 1943 trials. In 1942, the only plot where fertilizer combinations were added that resulted in more plants than the check was the 0-20-20 plot. The 20-20-20 fertilizer combination produced less stand than the 0-20-20 in 1942 and lower stand counts and less yield than the 20-20-10 in 1943. The stand and yield of these fertilizer combinations in 1943 are shown graphically in Figures V and VI.

These results indicated that increased nitrogen in the complete fertilizer may reduce stand, and that a reduction of the amount of potassium in the complete fertilizer may increase stand and yield. This indication is further confirmed by the stand and yield of the plots where a high proportion of phosphate and low proportion of potash (0-30-4) were combined with varying amounts of nitrogen (5-30-4, 10-30-4, 15-30-4, 20-30-4). The plots where 0-30-4 was added had higher stand and yields than the plots where nitrogen was included in the combination, although the placement of 10-30-4 and 15-30-4 to the side of the seed resulted in increases in stand and yield compared to the check. As in 1942, the combination of phosphate and potash had a greater number of living plants than did a combination of nitrogen, phosphate, and potash. In the fertilizer ratio trials in 1943, plots receiving certain combinations of nitrogen, phosphate, and a low proportion of potash had a greater number of living peas at picking time, and heavier yields than the check plot.

The important distinction is this: While 0-20-20 in 1942 and 20-20-10 in 1943 resulted in more living peas at picking time than the unfertilized check planting, the stand of living peas where 0-30-4 was applied above the seed was significantly better than the stand of the check. Plots where 0-30-4 was applied to the side of the seed approached significance. The yield where 0-30-4 was applied above the seed was significantly higher than the yield of the check, and where 0-30-4 was applied beside the seed, it approached significance.

To sum it all up: plots receiving certain complete fertilizers had better stands and yield than the check plots, but a combination of phosphate and potassium (0-30-4) placed above the seed had <u>significantly</u> better stands and yields than the unfertilized plots.

The results from the San Luis Valley are similar to the results of trials conducted at Fall River, Wisconsin, by the Wisconsin Agricultural Experiment Station (43,44). Tests using Alaska peas in 1939 showed that the most effective of the treatments used was 200 pounds of 0-20-10 per acre applied with the seed. Doubling the amount of potash reduced yields by nine percent, in contrast with the results at Columbus where 0-20-20 was best. Placing 0-20-10 in contact with the seed produced 54 percent more peas than the same amount of fertilizer drilled in bands to the side of the row. The explanation offered for the higher yields by the Wisconsin workers was that placing fertilizer in contact with the seed stimulated formation of root nodules.

In 1941 Wisconsin trials, the "best fertilizer application at Columbus was 200 pounds of 0-20-10 which increased yields 47 percent. At Randolph it took 300 pounds of this fertilizer for best results, but even 200 pounds increased yields by 25 percent. Using 300 pounds had the advantage of improving the quality of the peas at both locations.

It did not pay to use nitrogen in the fertilizer mixture. At Columbus 3 percent nitrogen actually reduced the yields somewhat, probably because it stimulated too much plant growth at the expense of root development.

In 1941 phosphate and potash fertilizer placed directly with the seed brought about slightly higher yields than fertilizer drilled at the side, but the difference was too small to be considered significant. Placing fertilizer with the seed has been the better practice during most years, so long as amounts have not exceeded 300 pounds per acre."

A comparison of the trials in Wisconsin and in the San Luis Valley of Colorado showed certain similarities of results. Both trials indicated that a combination of phosphate and potash was the most effective fertilizer. Both trials indicated that an excess of potash reduced yield, the use of nitrogen in the fertilizer mixture did not pay, and the placement of a combination phosphate and potash fertilizer in close contact with the seed gave higher yields than the same fertilizer placed in bands to the side of the row.

San Luis Valley compared to northern Colorado

The San Luis Valley area is the most important pod pea producing area in Colorado, but the trials at

Fort Cöllins, in northern Colorado, show that experiments not conducted under the San Luis Valley conditions may not apply to San Luis Valley practices. The differences in soil fertility, soil type, differences caused by subirrigation methods in contrast to furrow irrigation, a difference of 2500 feet in elevation, the contrast between eight and approximately 15 inches average annual precipitation, differences in fertilizer placement, and differences in soil borne root rot organisms all may contribute to the differences in results in the San Luis Valley as compared to northern Colorado.

In both areas a combination of phosphate and potash (0-20-20 at Fort Collins and 0-30-4 in the San Luis Valley) resulted in significant increases in stand and yield of peas, compared to the check. The 1942 trials in the San Luis Valley also showed an increase in stand from a phosphate-potash combination (0-20-20). In the 1943 trials in the San Luis Valley, the addition of a 0-20-20 fertilizer reduced stand and yield compared to the check.

The combination of nitrogen and potash showed comparable results in both areas. The 20-0-20 plot at Fort Collins had significantly more dead plants at picking time than did the plot where phosphate was included in the combination (20-10-20). In the San

Luis Valley, the 20-0-20 plot had significantly fewer living plants at picking time than plots where phosphate was included in the combination (20-10-20 and 20-20-20).

The yield response of peas to other fertilizer additions in the two areas showed great divergence. In the San Luis Valley fertilizer ratio trials, the total yields heavier than the check yield came from additions of nitrogen or phosphate alone or from the 20-20-10 combination. At Fort Collins the highest total yield resulted from the plots where nitrogen had been combined with other fertilizers, with the best four treatments containing both nitrogen and potash. The increase in yield from combinations containing both nitrogen and potash is in contrast to the San Luis Valley where such a combination (20-0-20) resulted in the poorest emergence, stand, and yield.

Factors modifying the effects of fertilizer applications

A number of variables affect the relation of soil fertility to losses in stand and yield from root rot, and thus influence the value of fertilizer additions to the soil to reduce such losses.

Tests in New York on the production of canning peas have shown that the full value of either fertilizer or seed protectant was realized only when they were used together (16). In the San Luis Valley, where the use of treated seed is necessary to get a satisfactory stand, the application of fertilizers to the soil would be of little value without seed treatment to insure emergence.

Both seed treatment and fertilizer additions to the soil may increase the ability of the plant to survive. The seed treatment is believed to effect this by the protection afforded the seed and its food reserves (4,17), while the addition of fertilizers to the soil increases the supply of nutrients which can be absorbed by the roots of the peas. For this reason, a more efficient seed treatment may result in better stand and yield than a combination of fertilizers and a less efficient seed treatment. Spergon was the seed treatment used in the 1943 trials in the San Luis Valley, but greenhouse experiments on San Luis Valley soil and field trials at the Demonstration Farm at Center indicated that New Improved Ceresan was more effective in reducing stand losses. These same greenhouse experiments showed significant interactions between seed treatments and fertilizers. The addition of certain fertilizers reduced significantly the emergence of Spergon-or Arasan-treated seed. In contrast, the addition of the same fertilizers to the soil did not significantly reduce the emergence of Cuprocide- or Arasan-treated seed. This indicated that some seed treatments may be better than others when certain fertilizer combinations are added to the soil. When N, P, K, NK, NP or lime was added to the soil, the stand from Ceresan-treated seed was significantly higher than the stand from Spergon-treated seed.

The work of Forsberg (11) has indicated that certain seed treatments are more effective in controlling seed-rotting organisms than are others. It is possible that the additions of certain fertilizers may increase the growth and virulence of organisms that are not checked by less efficient seed treatments, or the resistance of the host may be correspondingly increased or decreased. As a result, the additions of certain fertilizers may result in losses in stand with some seed treatments and no loss of stand with other seed treatments.

Trials by Parker (26) in Virginia showed that the smallest average yields resulted from fertilizers placed in a band directly beneath the seed and from fertilizers mixed with the surface soil at the time of planting. Intermediate yields were obtained from fertilizers placed on top of the row after planting and fertilizers used as sidedressing. The largest average yields of snap beans, lima beans, and peas resulted from placing the fertilizer in bands two inches to each side and two inches below the level of the seed at the time of planting. Parker concluded that fertilizer mixed with the surface soil or placed in a band directly beneath the seed produced small yields principally because of injury to the germinating seed and young seedlings.

The better yields obtained in the Virginia trials (26) from the side placement of the fertilizer may be attributed to several factors among which is the absence of injury at any state of plant growth. The germination counts of the seed showed that this placement produced as many and sometimes more plants than did the unfertilized control. The absence of any appreciable lateral movement of the fertilizer salts undoubtedly prevented the establishment of a toxic solution in the vicinity of the seedling roots, since an analysis of samples of soil taken from the area between the bands of fertilizer in the field showed only a very slight increase in the salt concentration during a period after planting. Most of the salts remained concentrated in the bands throughout this period. Germination in greenhouse trials was not appreciably influenced by this placement of the fertilizer in either moist or comparatively dry soil.

Another reason for the superiority of the side placement found in Virginia (26) was the greater availability of the fertilizer. The concentration of fertilizer in bands greatly reduced the rate of phosphorus fixation as shown by analysis of soils taken at regular intervals after planting. Samples taken as late as nineteen days after planting still showed a positive test for available phosphorus in the soil near the fertilizer bands, while that taken from areas where the fertilizer was mixed with the soil showed smaller amounts to be available.

Fertilizer located in a band directly beneath the seed caused the greatest loss of plants and resulted in the smallest yield of all placements of the fertilizer. The fertilizer placed in this position was sufficiently toxic to destroy the tap root of many of the plants and to cause a high mortality of the seedlings when the soil moisture content was relatively low.

The results of the trials conducted in the San Luis Valley and in northern Colorado followed the general trend of the Virginia trials, although the Colorado trials with one exception were not designed to study the effects of fertilizer placement.

The placement of ammonium sulfate below the seed, in the 1942 trials in the San Luis Valley, resulted in injury to the plants, reducing emergence and the number of living plants at picking time. The stand was so poor that no yield records were taken. The placement of fertilizer above the seed resulted in some injury and some increases in emergence and yield in the 1943 trials in the San Luis Valley, while the placement of the same series of fertilizers two inches to the side of the seed in both locations in 1943 showed little injury to emergence, and increases in yield and stand. In the single test designed to study the effect of placement, the complete fertilizers placed above the seed decreased stand and yield progressively with the amount of nitrogen added, while the same series of fertilizers placed to the side of the seed acted to increase the number of peas at picking time and increase yield significantly when compared to the same fertilizer placed above the seed.

The greater availability of phosphate when applied in bands beside the seed may also explain the increases in stand of some of the phosphate trials as compared to the slight increase in stand when phosphate was mixed in the soil with a grain drill as in 1938. The high pH and relatively high calcium content of San Luis Valley soils tend to fix phosphate in a form not readily available to the peas. A 0-30-4 mixture applied in bands above or beside the seed was significantly better or almost significantly better than the unfertilized plots in 1943.

The movement of easily soluble fertilizers is for the most part in a vertical rather than a horizontal direction. This means that a quickly soluble fertilizer placed above or below the seed comes in contact with the seed much sooner than the same fertilizer placed to the side of the seed. Ammonium sulfate injures the germinating seedling when applied in large enough amounts. For that reason, increasing amounts of ammonium sulfate added with 0-30-4 and placed above the seed resulted in stand decreases, which was reflected in yield losses. When the same fertilizer was applied two inches to the side of the seed, the fertilizer dissolved in the soil water did not come into contact with the seed or the seedlings' roots until the solution was too weak to be injurious. As a result, placement of the same series of fertilizers beside the seed did not reduce emergence, compared to the 0-30-4 plot to the same extent, and progressively, as did a similar series placed above the seed.

In the Fort Collins trials, the placement of the fertilizer in a single band to the side of the seed showed significant increases in stand and yield.

Wisconsin trials in the Fall River area (43) showed that 0-20-10 placed in contact with the seed produced 54 percent more peas than the same fertilizer drilled in bands to the side of the row. Comparable results were obtained from the San Luis Valley trials where 0-30-4 placed above the seed resulted in higher stands and yields than did the same fertilizer placed to the side of the seed.

The trials in the San Luis Valley and northern Colorado indicated that the placement is an important factor in the use of fertilizers to reduce losses from root rot. These trials indicated that the placement of fertilizers containing nitrogen above or below the seed usually resulted in significant losses in stand and yield, while placement to the side of the seed resulted in increases in yield in northern Colorado, and to a certain extent in the San Luis Valley. The placement of 0-30-4 above the seed resulted in higher yields than the placement of the same fertilizer beside the seed.

The work in Virginia (26) indicated that a higher mortality of seedlings resulted from fertilizers placed in a band directly beneath the seed when the soil moisture content was low. The placement of fertilizers beneath the seed when the soils were comparatively dry at planting time, as in 1942 San Luis Valley trials also resulted in a high mortality of seedlings, especially when ammonium sulfate, alone or in combination, was added.

The 1943 trials in the San Luis Valley showed evidence of further modification of the effects of fertilizer by water relations. The plots or rows closest to the ditches supplying water for subirrigation had significantly lower stand of living peas at picking time and lower yields as a result. Most of the soil borne organisms responsible for root rot are more likely to cause infection of the plants (13) or reduce emergence (14) when water is abundant. This may explain the loss in living plants planted close to the subirrigation ditches. This opinion does not refute the practice of raising the water table to keep plants already badly infected supplied with ample water.

The 1943 phosphate and potash trials were located near a small-grain field, and the soil in the replication closest to the grain field was much drier at planting time. The addition of phosphate or potash fertilizer in this comparatively dry replication resulted in greater proportional injury to stand and yield than in the plots where the soil held more moisture. This injury again was probably a result of the higher concentration of dissolved salts when less moisture was present.

SUMMARY

The object of the investigations was to study the effects of nitrogen, phosphate, and potassium on the stand and yield of pod peas grown in soils heavily infested with root rotting organisms, principally Fusarium solani v. martii f_2. These trials were conducted in 1943 in northern Colorado, in the San Luis Valley, and in the greenhouse, where San Luis Valley soil was used.

In the San Luis Valley fertilizers applied singly or in combinations to the soil significantly altered stand and yield. The response from fertilizers was modified by placement of fertilizer. An increase in the amount of nitrogen in a complete fertilizer resulted in significant decreases in stand when it was placed above the seed, but no significant decreases occurred when the same fertilizers were placed two inches to the side of the seed.

In general, a fertilizer treatment that caused reduced stand also caused reduced yield, when compared to unfertilized checks. However, the addition of increasing amounts of phosphate to the soil resulted in slight decreases in stand and increased yields. The largest yields resulted from the heaviest application

of phosphate. Poor stands and yields resulted when phosphate was omitted from a fertilizer combination containing nitrogen and potassium, while comparatively better stands and yields were obtained when a complete fertilizer containing nitrogen, phosphate and potassium was applied.

In the San Luis Valley the only fertilizer combination that caused significant increases in stand and yield compared to the unfertilized check planting was a combination of phosphate and potash (0-30-4) applied above the seed at the rate of 200 pounds per acre.

In the Fort Collins trials the plot with the highest number of living plants at picking time also received a combination of phosphate and potash. The greatest number of dead plants was found on the plots where a combination of nitrogen and potash was applied, and where phosphate was absent from the combination. At Fort Collins the addition of complete fertilizers resulted in the best yields, with the nitrogen component increasing total yields, the phosphate delaying the death of plants from root rot, and the potash increasing the yield from the second picking.

In greenhouse trials Ceresan-, Arasan-, Spergon-, and Cuprocide-treated seed were planted in San Luis Valley soils where various fertilizers had been applied singly and in combination. Better stands than in the unfertilized check were obtained with all four seed treatments when a combination of phosphate and potash was added to the soil. The poorest stand of plants grown from Spergon-treated seed occurred when a combination of nitrogen and potash was added to the soil.

The addition of sodium chloride from 3000 to 5000 parts per million to San Luis Valley soil resulted in a delay in emergence of pea seedlings, but had no significant effect on the total emergence. Adding fertilizer to soils containing the various salt concentrations did not increase the speed of emergence. The number of living plants recorded eight weeks after emergence decreased as the amount of sodium chloride added to the soil increased, regardless of fertilizer additions.

The almost complete absence of root rot infection of peas in steamed San Luis Valley soil indicates that soil-borne disease organisms are more important in stand reduction than the organisms carried on the surface of the seed. Preliminary results indicated that the seed treatment used (Ceresan) was more effective in reducing stand losses during the first six weeks period of growth than are fertilizers.

LITERATURE CITED 1/

(1) Afanasiev, M. M., and H. E. Morris
1942. Control of seedling diseases of sugar beets in Montana. Phyt. 32:477-486.

(2) Boswell, V. R.
1929. Factors influencing yield and quality of peas--biophysical and biochemical studies. Md. Ag. Exp. B. 306:341-382.

(3) Bowers, J. L., and C. H. Mahoney.
1940. Influence of nitrogen, phosphorus and potassium on the yield of Alaska peas grown on soils of known fertility level. Am. Soc. Hort. Sci. Proc. (1939) 37:707-712.

(4) Brett, C. C. and others.
1937. Seed disinfection; experiments on the germination of peas; seed protection by the use of disinfectant dusts containing mercury. J. Ag. Sci. 27:53-66.

(5) Buchholtz, W. F.
1943. Mop up those vegetable diseases before you plant! S. D. Ag. Ext. Leaflet 76:1-6.

(6) Carolus, R. L.
1938. Effect of certain ions, used singly and in combination, on the growth and potassium, calcium, and magnesium absorption of the bean plant. Plant Physiology 13:349-363.

(7) Chester, K. S.
1942. The nature and prevention of plant diseases. Philadelphia, Pa., The Blakiston Company. 584 p.

1/ Titles of articles and abbreviations used in descriptions of publications are those used by The Agricultural Index, H. W. Wilson Co., New York.

(8) Colorado Agricultural Experiment Station. Horticulture Section.
1939. Foot rots of pod peas. Fifty-second Annual Report, 1938-1939:33.

(9) Colorado State Planning Commission.
1943. Colorado agricultural statistics 1941. Denver, Colorado. 122 p.

(10) Davis, J. F. and others.
1942. Method of statistical analysis of a factorial experiment involving influence of fertilizer analyses and placement of fertilizer on stand and yield of cannery peas. Am. Soc. Agron. J. 34:521-532.

(11) Forsberg, J. L.
1943. Seed treatment aids against pea root rot if disease is not too concentrated in soil. Colo. Ag. Exp. Farm B. 5(2):5-8.

(12) Haensler, C. M.
1931. Use of fertilizers in reducing losses from pea-root rot caused by *Aphanomyces euteiches*. (abst.) Phyt. 21:116-117.

(13) Harter, L. L. and others.
1934. Pea diseases and their control. U. S. Dept. of Ag. Farmers' B. 1735:1-24.

(14) Hull, R.
1937. Effect of environmental conditions and more particularly of soil moisture upon the emergence of peas. Ann. Appl. Biol. 24:681-689.

(15) Jodidi, S. L., and V. R. Boswell.
1934. Chemical composition and yield of the Alaska pea as influenced by certain fertilizers and by the stage of development. J. Ag. Research, 48: 703-736.

(16) McNew, G. L.
1943. Effect of soil fertility on returns from the use of fungicides. The Canner. 96(7):14,15,42,44.

(17) McNew, G. L.
1943. Pea seed treatments as crop insurance. The Canner, 96(13): 16-19,26,28.

(18) Millar, C. E. and others.
1938. Fertilizers for white pea beans. Mich. Ag. Exp. Spec. B., 296:1-45.

(19) Musbach, F. L.
1934. Method of fertilizer application for canning peas. Am. Soc. Agron. J. 26:70-74.

(20) - - - - - - - - - and O. E. Sell.
1936. Effect of fertilizer on quality and chemical composition of canning peas. J. Ag. Research, 53: 869-879.

(21) New Jersey Agricultural Experiment Station.
1928-38. Pea root rot. N. J. Ag. Exp. Annual Report,(1927-28) 49:55-56, 1928; (1929-30) 51:48, 1930; (1934-35) 56:68, 1935; (1935-36) 57:73-74, 1936; (1937-38) 59:83, 1938.

(22) - - - - - - - - -
1929. Fertilizers vs. pea root rot. N. J. Ag. Exp. Annual Report, (1928-29) 50:41.

(23) - - - - - - - - -
1931-34. Peas. N. J. Ag. Exp. Annual Report, (1930-31) 52:50, 1931; (1931-33) 53-54: 61, 1933; (1933-34) 55:67-68, 1934.

(24) - - - - - - - - -
1937-39 Pea root rot investigations. N. J. Ag. Exp. Annual Report, (1936-37) 58:80, 1937; (1938-39) 60:93, 1939.

(25) New York State Agricultural Experiment Station, Division of Vegetable Crops.
1935. Fertilizer Experiments. N. Y. State Ag. Exp. Fifty-fourth Annual Report, 81-83.

(26) Parker, M. M.
1942. Truck crop investigations; effect of fertilizer placement on snap beans, lima beans and peas. Va. Truck Exp. B. 107:1759-1781.

(27) - - - - - - - - - - and R. C. Oliver.
1939. Effect of fertilizer placement, as influenced by soil moisture, on seed germination. Am. Soc. Hort. Sci. Proc. (1938) 36:533-536.

(28) Post, K.
1940. Effects of mineral-nutrient deficiencies and excesses upon the vegetative growth and flowering of sweet peas. Cornell Ag. Exp. B. 745: 1-27.

(29) Reinking, O. A.
1942. Distribution and relative importance of various fungi associated with pea root-rot in commercial pea-growing areas in New York. N. Y. State Ag. Exp. (Geneva) Tech. B. 264: 1-43.

(30) Sayre, C. B.
1935. Root development of beans, cabbage and tomatoes as affected by fertilizer placement. Am. Soc. Hort. Sci. Proc. (1934) 32:564-571.

(31) - - - - - - - - - -, and A. W. Clark.
1935. Rates of solution and movement of different fertilizers in the soil and the effects of the fertilizers on the germination and root development of beans. N. Y. State Ag. Exp. Tech. B. 231: 1-67.

(32) - - - - - - - - - -, and G. A. Cumings.
1936. Fertilizer placement for cannery peas. N. Y. State Exp. B. 659: 1-30.

(33) - - - - - - - - - -, and B. R. Nebel.
1931. Some effects of different nutrient solutions on the structure, composition and quality of peas. Am. Soc. Hort. Sci. Proc. (1930) 27: 221-226.

(34) - - - - - - - - -, and others.
1931. Factors affecting the quality of commercial canning peas. N. Y. State Ag. Exp. Tech. B. 176: 1-76.

(35) Schroeder, W. T., and J. C. Walker.
1942. Influence of controlled environment and nutrition on the resistance of garden pea to fusarium wilt. J. Ag. Research, 65: 221-248.

(36) Smith, P. G., and J. C. Walker.
1941. Certain environal and nutritional factors affecting aphanomyces root rot of garden pea. J. Ag. Research, 63: 1-20.

(37) Smith, R. E.
1940. Diseases of truck crops. Cal. Ag. Ext. C. 119:1-112.

(38) Snyder, W. C., and H. N. Hansen.
1941. The species concept in Fusarium with reference to section Martiella. Am. J. Bot. 28:738-742.

(39) Wingard, S. A.
1941. Nature of disease resistance in plants. Bot. R. 7:59-109.

(40) Walker, J. C.
1933. Relation of soil fertility to incidence of aphanomyces root rot of peas. (abst.) Phyt. 23:36.

(41) - - - - - - - - - and F. L. Musbach.
1939. Effect of moisture, fertility, and fertilizer placement on root rot of canning peas in Wisconsin. J. Ag. Research, 59: 579-590.

(42) - - - - - - - - - and W. C. Snyder.
1942. Pea wilt and root rots. Wis. Ag. Exp. B. (rev.) 424:1-16.

(43) Wisconsin Agricultural Experiment Station.
1941. Fertilization increases yields of canning peas. What's new in farm science. (Annual Report, 1940, Part II). Wis. Ag. Exp. B. 449:8-9.

(44) - - - - - - - - -
1942. Canning peas pay well for fertilizer. What's new in farm science. (Annual Report, 1941, Part II). Wis. Ag. Exp. B. 455:57-58.