EFFECTS OF NITROGEN AND PHOSPHORUS ON THE GROWTH AND DEVELOPMENT OF RUSSET BURBANK POTATOES GROWN IN SOUTHEASTERN IDAHO[1]

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INTRODUCTION

It was observed, in reviewing previous data from Idaho,[3] that the yield response to increasing rates of nitrogen and phosphorus fertilizers was generally positive up to a particular rate, above which the response often became negative. The result is reduced total yield and/or yield of U.S. No. 1 potatoes.

It is more generally known that excess nitrogen can cause yield reductions. But it is not generally known that excessive rates of phosphorus may limit yields. As a result of these observations a study was conducted, part of which is reported herein, to determine the effects of both nitrogen and phosphorus on the growth and development of Russet Burbank potatoes grown in southeastern Idaho.

Idaho has had an active potato fertility research program for over 25 years. Nitrogen and phosphorus are the fertilizer elements most often found limiting (6, 7). Insufficient or excess rates of fertilizer or incorrect ratios often resulted in negative responses and/or quality reductions.

It had been reported that excessive rates of nitrogen may result in reduced yields and specific gravity, increased knobbiness and poorer netting (6, 7, 9). But these effects could be overcome by proper nitrogen rates and nitrogen-phosphorus balance.

However, excessive rates of phosphorus hadn't been considered as having an undesirable effect on potato production in this area. Harrington (2) in Montana reported a case where excess phosphorus reduced the yield of potatoes. This effect was overcome by incorporating organic matter into the soil. Painter (6) in Idaho, reported that excess phosphorus depressed the yield of U.S. No. 1 potatoes on newly developed desert land. Recently Sommerfeldt (9) summarized the more current fertilizer studies on potatoes in Idaho. In this summary it was found that in more than 50% of the cases when the phosphorus rates exceeded a particular limit the yield of U.S. No. 1 potatoes was somewhat reduced. The point at which phosphorus fertilizer became excessive was dependent upon the land on which the trial was established.

In California, Lorenz et al. (4) reported favorable responses to both nitrogen and phosphorus. However, there was a particular rate for each, which varied with locations, in which the greatest responses were obtained.

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[3]Sources of information were annual reports from 1956-1960, and Painter and Baker, Bulletin 281, listed in literature cited.

Generally with rates less than the optimum, marked yield reductions were observed and for excessive rates, yield increases, if any were not appreciable. In some cases the responses were negative to high rates of nitrogen and phosphorus.

For maximum production, Haddock (1) reported that potatoes need to be well nourished and that the proper balance of nitrogen, phosphorus and potassium in the plant was more important than the total concentration of these nutrients in the leaves.

Apparently the roles of nitrogen and phosphorus in plant metabolism are in some ways interrelated. According to Meyer, et al. (5), the inorganic-nitrogen absorption by a plant is inversely related to the phosphorus concentration in the root zone. Plants mature earlier when there is an abundance of phosphorus in the root zone and maturity is delayed when there is a deficiency. The application of phosphorus fertilizer may reduce the nitrogen balance of the plant, thus hastening its maturity.

Further, according to Hardenburg (2), the uptake of nutrients by the potato plant is not necessarily in accordance with what the plant needs for maximum development and yield. It is influenced by several soil conditions, including soil fertility. Excessive nitrogen can cause the plant to become vegetative at the expense of tuberization.

Two approaches to this problem were used: Field trials supplemented with laboratory analyses; and greenhouse trials.

There were two field trials similar in design, one in 1962 and the other in 1963. In 1962 questions arose whether soil type and/or disease could have been secondary factors contributing to the results obtained. In 1963 a similar trial was established on a "benchmark" soil (Declo loam), which had been fumigated prior to planting to reduce the potential of the soil borne pathogens. The results from the 1963 trial confirm those of 1962, and will be used in this report.

Materials and Methods

A. *Field studies*

Two trials will be reported. One was a nitrogen-phosphorus fertilizer trial; the other, a fumigation-nitrogen trial. Both were on the same field and directly adjoining.

Soil characteristics: pH 7.6, soluble salts (E.6 x 10^3 satn. paste) 1.0, organic matter 1.5%, phosphorus (CO_2 sol.P) 37 lbs. per acre (high), potassium (K) 464 lbs. per acre.

1) *Nitrogen-phosphorus fertilizer trial*

Prior to seedbed preparation and fertilizer applications, the soil was fumigated with chloropicrin at the rate of 20 gal. per acre. This was placed in rows 12 inches apart and at a depth of 10 inches with a chisel applicator. Following placement of the fumigant the soil surface was sealed by firmly packing with a culti-packer. At the time of fumigation the soil moisture was near field capacity and soil temperature at 8-inch depth was 55 F.

Different rates of nitrogen and phosphorus were broadcast by hand, singly and in combination in a factorial design and replicated five times. The rates were 0, 80, and 160 lb per acre of N and 0, 35, 70 and 106 lb per acre of P. These were worked into the soil during the seedbed preparation.

The plot size was 12 feet wide (four rows) by 30 feet long. For harvest, 20 feet from each of the two center rows were used.

Leaf samples (blade plus petiole) were collected at 9 to 10 day intervals for analysis. This was begun when the first mature leaves appeared (July 8) and continued over a two-month period.

To collect and prepare a leaf sample, the first mature leaf from the top, generally the fourth, was taken from 20 plants of the two center rows. These were placed in Kraft paper bags and dried in a forced draft oven at 60 C. The dried leaves were then pulverized in a Waring blendor and analyzed for 2% acetic acid soluble nitrate-nitrogen and phosphorus, and total potassium, calcium, and sodium content.

On August 7, stem samples were collected for analysis. The stem was divided into three sections; underground, middle (first 6 to 8 inches above ground) and top (the remainder). These were washed with distilled water, then dried, pulverized and analyzed in the same manner and for the same elements, plus magnesium, as were the leaves.

The methods of analyses used are as follows: Nitrate-nitrogen by the brucine method; phosphorus by the ammonium molybdate method; potassium and sodium with a Coleman flame photometer; and calcium and magnesium by the versenate method.

The potatoes were dug, picked, bagged and stored about three weeks. Then the potatoes were washed, graded, weighed and the specific gravity determined.

2) *Fumigation-nitrogen trial*

A split plot design, with the units arranged in randomized blocks, was used for this study. The main plots were soil fumigation versus non-fumigation and the subplots were nitrogen rates (0, 40, 80, and 160 lb per acre).

Fumigation, fertilization, and management of this trial were the same as for the fertilizer trial except the fumigant rate was 25 gal per acre and there were no stem analyses.

The plot size was 18 feet wide (six rows) by 60 feet long. For harvest, 40 feet from each of the two center rows were used.

B. *Greenhouse studies*

The effects of nitrogen and phosphorus on growth and development of potatoes were also studied in two greenhouse experiments. In one, only the effects of nitrogen and phosphorus were studied. Treatments were replicated 12 times. In the other, micro elements (zinc, iron, and manganese at the rate of 9 lb per acre of each) were superimposed on the nitrogen and phosphorus treatments to determine their effects on the growth and development of potatoes. This was replicated three times.

The nitrogen and phosphorus fertilizer rates were 0, 60, 120, and 240 lb per acre of N and 0, 35, 70, and 106 lb per acre of P. These were applied singly and in combination in a factorial design. (The rates are based on an acre foot of soil by volume.)

Potatoes were planted in pots containing 1500 grams of soil with a bulk density of 1.0. At planting time the fertilizer treatments were incorporated and thoroughly mixed into the soil. Rate of emergence and plant growth rate throughout the experiment were determined. At the end of the trial the dry weight of tops and roots, and the tuber set and yield were determined.

Results

A. *Field studies*

1) *Nitrogen-phosphorus fertilizer trial*

Vegetative responses to nitrogen and phosphorus were not apparent until the latter part of the season. The vines were more rank and had a darker green color and maturity was delayed a few days from nitrogen as compared to phosphorus.

Only the yields of U.S. No. 1 potatoes over 10 oz and undersized potatoes were significantly affected by fertilizers. A yield increase of U.S. No. 1 potatoes over 10 oz resulted from nitrogen fertilizer, significant at the 5% level, with the maxixmum occurring at the 80 lb per acre rate (see N means of Table 1). Excessively high rates of phosphorus fertilizer resulted in reduced yields of U.S. No. 1 potatoes over 10 oz (see P means of Table 1), and increased yields of undesired potatoes (see P means of Table 2), both significant at the 5% level.

Yield of U.S. No. 1 potatoes over 10 oz was affected by a nitrogen-phosphorus interaction effect, significant at the 1% level (Table 1). The yield increased with nitrogen and decreased with increased phosphorus rates. The phosphorus effects increased with nitrogen rates.

Yield of undersized potatoes was also affected by a nitrogen-phosphorus interaction, significant at the 5% level (Table 2). The amount of undersized potatoes was decreased by nitrogen and increased by phosphorus. The phosphorus effect was somewhat enhanced by the presence of nitrogen.

Both nitrogen and phosphorus fertilization affected the concentration of different elments in the plant tissue. Increasing rates of nitrogen fertilizer increased the nitrate-nitrogen and calcium content and decreased the phosphorus content of the stem and/or leaf tissues. Phosphorus reduced the nitrate-nitrogen and calcium, and increased the phosphorus and magnesium contents of the stem and/or leaf tissues.

2) *Fumigation-nitrogen trial*

Total yield was increased from 176 to 286 cwt per acre by fumigation. Yield of U.S. No. 1 potatoes was increased from 126 to 216 cwt per acre and that of U.S. No. 1 potatoes over 10 oz was increased from 22 to 71 cwt per acre as a result of fumigation. All are significant at the 1% level.

Only the yield of U.S. No. 1 potatoes was significantly affected by nitrogen fertilization. The 40-lb per acre rate was as effective as any other rate. At the 40-lb per acre rate, yield was increased from 150 to 188 cwt per acre, significant at the 5% level.

Fumigation and nitrogen treatments had no significant effects on the nutrient content of the leaf tissue.

B. *Greenhouse studies*

The rates of emergence and plant growth were both affected by treatment (Fig. 1). Only the two extremes are shown. High rates of phosphorus slightly delayed emergence but accelerated the growth rate

TABLE 1.—*Nitrogen and phosphorus fertilizer effects on the yield (cwt/Acre) of U.S. No. 1 over 10 ounce potatoes.*

Nitrogen	P lb/Acre				
lbs/Acre	0	35	70	106	Mean
0	35	36	35	31	34 e
80	58	59	51	35	51 f
160	60	52	35	35	46 f
Mean	51 b	49 b	40 ab	34 a	

Nitrogen effect significant at the 5% level.
Phosphorus effect significant at the 5% level.
Interaction effect significant at the 1% level.
Means with the same letter within a column or row do not differ at the 5% level of probability as calculated by Duncan's Multiple Range Test.

TABLE 2.—*Nitrogen and phosphorus fertilizer effects on the yield (cwt/Acre) of undersized potatoes.*

Nitrogen	P lb/Acre				
lbs/Acre	0	35	70	106	Mean
0	35	31	36	32	33
80	29	30	27	43	32
160	28	30	38	37	33
Mean	31 a	30 a	34 ab	37 b	

Nitrogen effect not significant.
Phosphorus effect significant at the 5% level.
Interaction effect significant at the 1% level.
Means with the same letter do not differ at the 5% level of probability as calculated by Duncan's Multiple Range Test.

after emergence, especially when in combination with nitrogen. Emergence was not affected by nitrogen but growth rate was reduced at the high rates early in the experiment and increased later. Generally the growth rate was greater the later the emergence. The point of intercept of all the growth curves was near April 2-6, which correspond to the late bud — early blossom stage of plant development.

The yield of tops was increased by both nitrogen and phosphorus fertilization, significant at the 1% level (Means Table 3). There was also a nitrogen-phosphorus interaction effect (Table 3). At the lower rates the responses to each fertilizer were additive. When nitrogen was applied at 120 lb per acre, 35 lb of phosphorus per acre gave a positive response but righer rates of phosphorus gave negative results. At the 240 lb per acre rate of nitrogen the results were similar except in combination with the 106 lb rate of phosphorus. Response to phosphorus at this rate was better than at the 70 lb rate but poorer than at the 35 lb per acre rate.

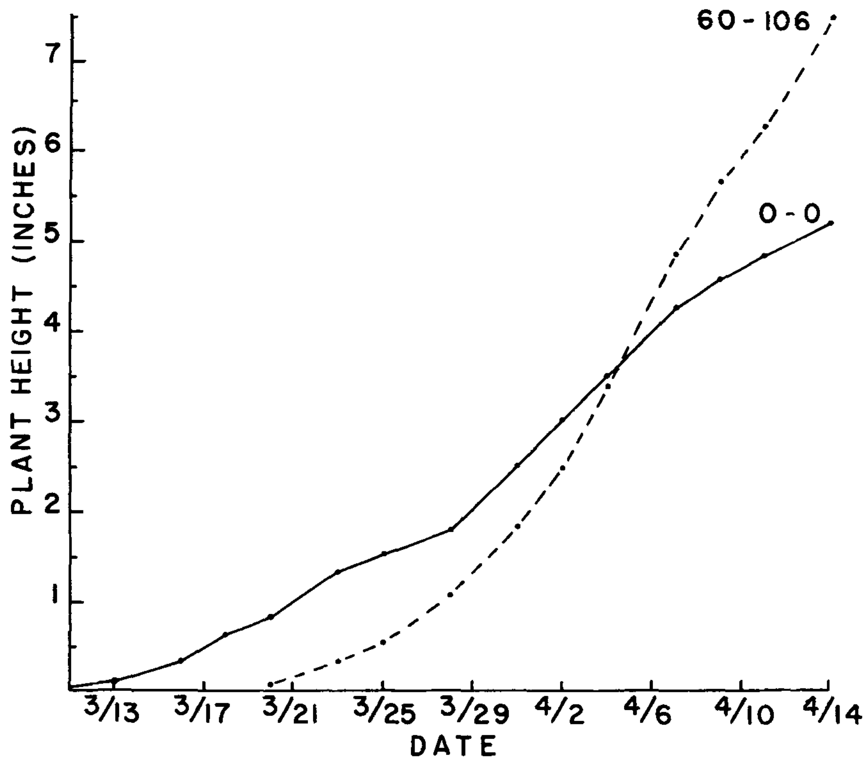

FIG. 1—Effect of fertilizer on plant emergence and growth rate. (0-0 and 60-106 are check and 60 lb per acre of nitrogen plus 106 lb per acre of phosphorus respectively.)

TABLE 3.—*Nitrogen and phosphorus fertilizer effects on the dry weight of tops (gms per pot).*

N	P lb/Acre				
lbs/Acre	0	35	70	106	
0	2.0	2.1	2.2	2.3	2.2 e
60	2.0	2.2	2.4	2.5	2.3 f
120	2.2	2.6	2.5	2.3	2.4 g
240	2.4	2.8	2.4	2.7	2.6 h
Mean	2.2 a	2.4 b	2.4 b	2.4 b	

Nitrogen effect significant at the 1% level.
Phosphorus effect significant at the 1% level.
Interaction effect significant at the 5% level.
Means with the same letter within a column or row do not differ at the 5% level of probability as calculated by Duncan's Multiple Range Test.

TABLE 4.—*Nitrogen and phosphorus fertilizer effects on the dry weight of roots (grams per pot).*

N	P lb/Acre				
lbs/Acre	0	35	70	106	Mean
0	1.1	0.9	0.9	0.9	1.0
60	0.8	1.0	0.9	0.8	0.9
120	0.9	1.0	0.9	0.7	0.9
240	0.9	1.0	0.8	0.9	0.9
Mean	0.9	1.0	0.9	0.8	

Nitrogen effect not significant.
Phosphorus effect not significant.
Interaction effect significant at the 5% level.

TABLE 5.—*Nitrogen and phosphorus interaction effects on the number of tubers set per plant.*

N	P lb/Acre				
lbs/Acre	0	35	70	106	Mean
0	0.9	0.8	1.8	1.6	1.3 d
60	1.2	1.1	1.0	0.4	0.9 c
120	0.5	0.9	0.0	0.2	0.4 b
240	0.0	0.3	0.0	0.1	0.1 a
Mean	0.6	0.8	0.7	6.6	

Nitrogen effect significant at the 1% level.
Phosphorus effect not significant.
Interaction effect significant at the 1% level.
Means with the same letter do not differ at the 5% level of probability as calculated by Duncan's Multiple Range test.

The root yield was not significanly affected by either nitrogen or phosphorus. But there was a nitrogen-phosphorus interaction effect, significant at the 5% level, such that the root yield was either reduced or not affected by fertilizer treatments (Table 4). The net result was increased top:root ratios at the higher fertilizer rates.

Tuber set was affected by nitrogen (Means Table 5) and a nitrogen-phosphorus interaction (Table 5), both significant at the 1% level. Nitrogen suppressed tuber set; phosphorus augmented it. Tuber set was doubled by the high rates of phosphorus alone. But when nitrogen was included in the treatments, the effect of nitrogen to suppress tuber set was apparently greater than that of phosphorus to augment it.

Excessive rates of both nitrogen and phosphorus reduced the average weight of tubers, significant at the 1% level (Table 6). At these rates of fertilizer the plant apparently became vegetative at the expense of tuber growth.

The authors feel micro elements as used in this study were not

TABLE 6.—*Nitrogen and phosphorus fertilizer effects on the mean tuber weight.*

N lbs/Acre	P lb/Acre 0	35	70	106	Mean
0	3.7	3.7	3.8	1.7	3.2 g
60	2.8	3.0	1.4	0.5	1.9 f
120	1.5	2.8	0.0	0.8	1.3 f
240	0.0	0.4	0.0	0.2	0.2 e
Mean	2.0 bc	2.5 c	1.3 ab	0.8 a	

Nitrogen effect significant at the 5% level.
Phosphorus effect significant at the 1% level.
Interaction effect significant at the 1% level.
Means with the same letter within a column or row do not differ at the 5% level of probability as calculated by Duncan's Multiple Range Test.

limiting, since the results from the trial including micro elements confirmed those from the trial without them. That is, the rate and ratio of nitrogen and phosphorus fertilizer are important factors in determining the optimum growth and development of potatoes.

The role of micro elements in the nutrition of Russet Burbank potatoes in southeastern Idaho is not fully understood at the present. Iritani[4] at the Aberdeen Branch Station has been testing various micro elements on potatoes for several years and hasn't observed response to them in this area. In 1964, a field trial, located near the one reported herein, included micro elements (zinc, iron, manganese, copper, and boron) in combination with high rates of nitrogen, phosphorus and potassium. The results of this trial indicated these micro elements were not limiting (Fig. 2). This does not preclude the possibility of micro element deficiencies in other trials.

DISCUSSION

Based upon these results it is evident that the growth and development of the potatoes were influenced by nitrogen and phosphorus fertilization. The rate and ratio of these fertilizers were important in determining optimum growth and development. Both insufficient and excess amounts as well as improper balance of these fertilizers were found to affect the growth and development in such a manner that tuber set and yield were limited.

Excess phosphorus resulted in reduced tuber size both in the field and greenhouse. The cause for this is not known. According to Russell (8) excess phosphorus sometimes reduces crop yields by hastening the maturation process. If such was the case in this study, it is evident the process began in the young plant. Tuber size was limited from greenhouse plants which were harvested after only one month's growth. This phosphorus effect is apparently a complex one and begins as soon as the plant begins growing. This is evidenced by its effect on emergence, growth and development of the plant and tissue analysis. Reduced tuber size and hastened maturity are apparently expressions of this effect.

[4]Personal communication.

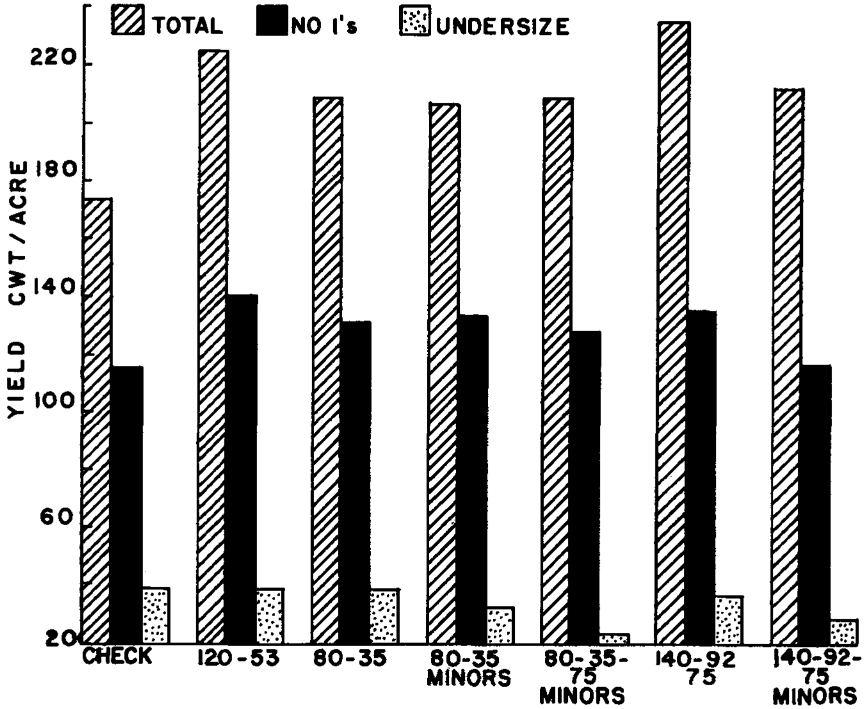

FIG. 2.—The effect of different fertilizers and rates on the total yield, yield of U.S. No. 1 and yield of undersized potatoes (cwt/Acre). The fertilizers were: nitrogen (N lb/Acre); phosphorus (P lb/Acre); potassium (K lb/Acre); and micro (zinc, 5 lb/Acre; manganese, 10 lb/Acre; copper, 0.75 lb/Acre; boron, 0.5 lb/Acre; iron, 5 lb/Acre).

As previously mentioned, Meyer et al. (5) reported that the roles of nitrogen and phosphorus in plant metabolism are apparently interrelated. They cite the effects of excess phosphorus in the root zone on nitrogen uptake; tissue analysis results from this study tend to confirm this. The nitrate-nitrogen content of stem tissue was depressed by phosphorus fertilization and the phosphorus content of leaf tissue was depressed by nirogen fertilization.

It is possible that absorption of calcium and magnesium was also affected by nitrogen and/or phosphorus. Calcium content of the stem was increased by nitrogen fertilization and depressed by phosphorus. Magnesium content of the stem was increased by phosphorus. This suggests that excessive nitrogen and/or phosphorus interfered with the plant's absorption and/or distribution of these elements.

SUMMARY

Field and greenhouse trials supplemented with laboratory analyses were used to study the effects of nitrogen and phosphorus on the growth

and development of Russet Burbank potatoes in southeastern Idaho.

Based on the results of this study, it appears that both nitrogen and phosphorus had direct effects on the growth and development of the potatoes. Both affected the concentration of different elements in the plant tissue (indicating the physiology of the plant had been affected), and tuber size. In the field, reduction in tuber size as a result of nitrogen alone was not evident, but it was evident in the greenhouse. Reduced tuber size as a result of phosphorus was evident in both the field and greenhouse studies. In the greenhouse, excess nitrogen reduced the tuber set; excess phosphorus delayed plant emergence; growth rate, primarily top growth, was increased by both nitrogen and phosphorus.

SUMARIO EN ESPAÑOL

Experimentos de campo e invernadero y análisis de laboratorio fueron llevados a cabo para es tudiar el efecto del nitrógeno y el fósforo sobre el crecimiento y desarrolo de la papa en el sureste de Idaho.

Los resultados demostraron que tanto el nitrógeno como el fósforo tienen efecto firecto sobre el crecimiento y desarrollo de la papa. Ambos elementos afectaron la concentración de diferentes componentes del tejido de la planta y tamaño del tubérculo. El tamaño del tubérculo no fué reducido en los experimentos de campo como resultado del nitrogeno solo, pero fué afectado en los experimentos de invernadero. El tamaño del tubérculo fué reducido con el uso del fosforo en los experimentos de campo e invernadero. En el invernadero el exceso de nitrógeno redujo el número de tubérculos; el exceso de fosforo retrasó la emergencia de la planta; tanto el nitrógeno como el fósforo aceleraron el crecimiento de la planta, especialmente las ramas.

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