THE EFFECT OF SOIL MOISTURE AND NITROGEN ON YIELD AND QUALITY OF THE RUSSET BURBANK POTATO[1]

C. G. Painter and J. Augustin[2]

Abstract

A study was conducted to obtain more information on the effects of soil moisture and nitrogen on yield and quality of the Russet Burbank potato.

Total yield of tubers increased with nitrogen rates as a result of more tubers per plant and larger tubers but the percent of malformed tubers also increased. Increased nitrogen rates decreased of dry matter of tubers and increased the total amino-nitrogen content of the tubers.

Placing all of the nitrogen in bands on each side of the row produced more tubers having growth cracks, culls and reduced yield of No. 1's when compared with broadcasting.

Applying a moisture stress to potato plants during the early tuber set period increased the percentage of malformed tubers having pointed stem ends, bottlenecks and dumbbell shapes; although total yield and grade of tubers were not significantly affected. Irrigating when available soil moisture was 75 or 85 percent instead of 65 percent during the growing season did not affect total yield, grade or tuber quality at the five percent probability level.

Resumen

Se realizó un estudio para obtener mayor información sobre los efectos de la humedad el nitrógeno sobre rendimiento y calidad de la papa Russet Burbank.

El rendimiento total de tubérculos incrementó las dosis de nitrógeno como resultado de un mayor número de tubéculos por planta y de su mayor tamaño; pero aumentó el porcentaje de tubérculos mal formados. Asimismo, el incremento de las dosis de nitrógeno decreció el porcentaje de materia seca e incrementó el contenido de nitrógeno total y amino de los tubérculos.

Colocando todo el nitrógeno en bandas a cada lado de la hilera, se produjo mayor numero de tubérculos con rajaduras, tubérculos sin valor comercial y redujo el rendimiento de tubérculos No. 1 en comparación con la incorporación del abono esparcido. Sometiendo las plantas de papa a un

[1] Approved for publication by the Director of the Agricultural Experiment Station, University of Idaho, Moscow, Idaho 83843 as Research Paper No. 7452.

[2] Respectively, Extension Professor, Extension Soils Specialist, Twin Falls, Idaho; Associate Research Professor of Food Science, University of Idaho, Moscow, Idaho.

Received for publication March 29, 1976.

periodo de deficit hídrico durante el inicio de la tuberización, se incrementó el porcentaje de tubérculos malformados con la zona apical alargada, constricciones y otras deformaciones, aunque el rendimiento total y el grado de los tubérculos no fueron significativamente afectados. Aumentando de 65% a 85% la humedad disponible previa a cada irrigación durante la estación de crecimiento, no afectó el rendimiento total, el grado o calidad de los tubérculos a nivel de 5% de significación estadística.

Introduction

Potatoes are one of the major crops grown in southwestern Idaho. Total yields for this area are the highest in the state; however, the percent No. 1 grade out is usually lower than in the other potato growing areas of the state. In 1971, poor tuber quality as a result of low solids and high reducing sugar ends produced many undesirable dark end French fries in processing.

These problems seemed more severe in southwestern Idaho than other areas. Consequently, it appeared desirable to obtain more information on how nitrogen fertilizer and moisture affected tuber quality in this area. The objectives of this study were to determine the effects of nitrogen rates and method of application and available soil moisture levels prior to irrigation on yield and quality of the Russet Burbank potato.

Literature Review

Research has demonstrated that nitrogen fertilizer and moisture affect tuber yield and quality. The effect appears to vary between localities and probably is due to differences in climate which affects growing season, temperatures and light intensity. For example, increasing nitrogen levels have been reported to cause a decrease in specific gravity (1, 3, 7, & 8), whereas, other reports (3, 11) indicated no effect on late harvested potatoes. Total yield generally increased with increased nitrogen rates (1, 2, 3, 7, 8 & 10) but in some cases a higher percentage of malformed tubers was produced (6, 7 & 8). Nitrogen fertilizer did not affect chip or French fry color (2 & 8) but did show more light skinned tubers (8). Banded or side dressed nitrogen was more efficient than broadcast nitrogen plowed down prior to planting (11) but nitrogen banded in spring as ammonium nitrate and calcium nitrate produced lower yields of number one tubers than when broadcasted in fall and plowed under. This effect was not noted from application of ammonium sulfate or on total yield of tubers (9).

Moisture stress early in the growing season resulted in more malformed tubers (4 & 5).

Materials and Methods

The experiment was located on a Greenleaf silt loam soil having a laminated silt layer at the 14-16 inch soil depth. This layer is permeable to water but restricts root penetration. The soil holds about two inches of available moisture per foot of soil depth. Potatoes followed barley in the crop rotation and the grain stubble was disced into the soil and fall plowed.

Soil samples were taken prior to fertilization and after potato harvest to determine nutrient levels and kind and rate of fertilizers to apply for potato production and to evaluate residual or nitrogen carry-over from nitrogen fertilization. The top two feet of soil contained 42 pounds per acre of nitrate-nitrogen prior to fertilization.

Nitrogen treatments consisted of three rates, 120, 240, and 360 pounds per acre. Nitrogen was (1) banded six inches deep and six inches to each side of row in 36 inch beds (2) broadcasted and worked into soil six to eight inches deep and (3) one-half was broadcasted and one-half was banded prior to planting for each rate.

Four moisture treatments were used. These were: (M1) available soil moisture was depleted down to 25 percent prior to soil irrigation during the period of early tuber set to 2 to 3 ounce tuber size and down to 65 percent during the remainder of the growing season; (M2) Available soil moisture was depleted down to 65 percent prior to each irrigation; (M3) Available soil moisture was depleted to 75 percent prior to each irrigation; and (M4) available soil moisture was depleted down to 85 percent prior to each irrigation. All irrigation treatments were terminated about 15 days prior to vine removal for potato harvest. The M1 treatment was designed to apply moisture stress to potato plants during early tuber set.

Moisture treatments were the main blocks, four rows wide and 265 feet long. These were randomized in each of four replications. Nitrogen rates and methods of application were randomized in each of the four moisture treatments in plots four rows wide and twenty feet long with five foot alleys between plots.

Nitrogen fertilizer was applied as ammonium sulfate. Phosphorus fertilizer was applied to all plots at 160 pounds P_2O_5 per acre as treble super phosphate (0-45-0).

Water was applied by furrow irrigation. Time of irrigation and amount of water to apply were determined by sampling soil at the 8-10 inch soil depth and oven drying for available moisture and measuring water on and off the plots for infiltration rates.

One to two ounce uncut tubers of certified Russet Burbank seed were planted April 12.

The 4th or 5th petiole from the terminal branches of potato plants was collected at early tuber set (55 days after planting) and analyzed for

two percent acetic acid extractable nitrate-nitrogen. All samples were analyzed by the Department of Plant and Soil Sciences laboratory in Moscow.

Tubers were harvested on October 3. Tubers from each plot were counted, weighed and graded for yield and quality. Classification of tubers was: total yield of all tubers; total No. 1's; percent No. 1's (by weight) large No. 1's (ten ounces and over in size); small No. 1's (four ounces and over and under ten ounces in size); large and small No. 2's and culls (small tubers less than four ounces). All No. 2 tubers were graded for stem pointed ends, knobs, growth cracks, bottleneck and dumbbell shaped tubers.

Specific gravity was determined by the weight in air and weight in water method.

Eight to ten pound samples of tubers were taken at harvest from each replicate of the banded 120, 240 and 360 pounds nitrogen per acre treatments across each of the M2 and M4 treatments. These samples were analyzed by the quality testing laboratory at Aberdeen, Idaho for dry matter; alcohol insoluble solids; starch; total and reducing sugars; total nitrogen; amino nitrogen (i.e. ninhydrin positive nitrogen); vitamins (ascorbic acid, thiamine, riboflavin and niacin); and minerals (Ca, Mg, K, Na, Fe and Cu.

Results and Discussion

Nitrogen Rates

Total yield of tubers per acre increased as nitrogen rates increased but the percentage of malformed tubers also increased (Figure 1). This is in agreement with past research (1, 2, 3, 6, 7, 8 & 10). The specific gravity of tubers decreased with increased nitrogen rates (Figure 2). This was shown by some research (1, 7). The high nitrogen rates reduced percent dry matter and ascorbic acid and increased amino and total nitrogen (Table 1).

The average nitrate-nitrogen in potato petioles at early tuber set increased with increased nitrogen rates. These levels were 23,167; 27,189 and 28,948 ppm for the 120, 240 and 360 pounds nitrogen per acre, respectively.

After harvest, nitrate-nitrogen in the top two feet of soil was higher on plots receiving 240 and 360 pounds nitrogen per acre and lower on the plot receiving 120 pounds nitrogen per acre, when compared with the nitrate-nitrogen level in the soil prior to fertilization.

These data show that fertilizing with nitrogen for maximum yield may result in production of low grade tubers with undesirable characteristics for the fresh market or processing.

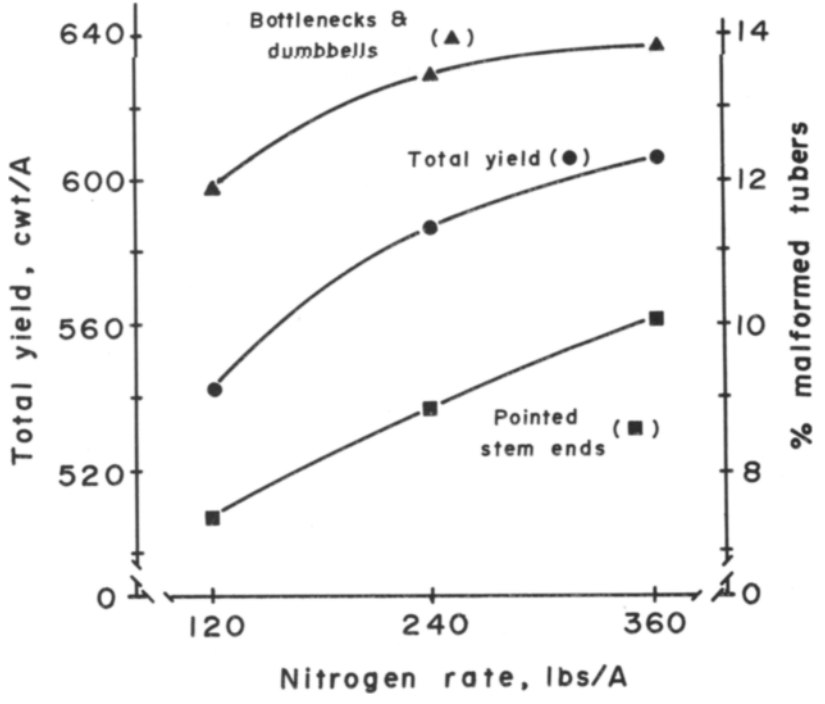

FIG. 1. Effect of nitrogen rates on total yield and malformed tubers.

FIG. 2. Effect of nitrogen rates on specific gravity of tubers.

TABLE 1. *Chemical composition as affected by nitrogen and moisture Variables*[1]

Variables	Lbs. nitrogen per acre			ASM[2]	
Measures	120	240	360	65%	85%
Dry Matter %	22.48	21.58	21.36	21.36	22.24
Alcohol insoluble Solids %	92.65	92.57	91.44	91.47	92.96
Crude Fiber %	1.08	1.17	1.10	1.17	1.06
Starch %	74.24	75.07	75.21	74.60	75.08
Reducing Sugars %	.55	.53	.47	.51	.52
Total Sugars %	1.28	1.28	1.23	1.23	1.30
Total Nitrogen %	1.16	1.41	1.43	1.39	1.27
Amino Nitrogen %	4.09	4.89	4.93	4.83	4.44
Ascorbic Acid mg/100g	92.08	85.65	87.37	88.44	88.29
Thiamin mg/100g	.73	.85	.81	.85	.74
Niacin mg/100g	10.08	9.23	12.79	9.95	11.44
Riboflavin mg/100g	.118	.111	.118	.127	.103
Ash %	4.20	4.24	4.24	4.37	4.08
Calcium %	.019	.021	.022	.022	.020
Magnesium %	.084	.077	.077	.077	.081
Potassium %	1.47	1.47	1.45	1.48	1.45
Sodium %	.022	.022	.021	.022	.022
Iron ppm	15.70	14.35	15.65	15.83	14.63
Copper ppm	1.30	.65	1.70	1.10	1.70

[1] All data except for drf matter are recorded on a dry weight basis.
[2] Available soil moisture prior to irrigation.

Nitrogen Placement

Broadcasting the nitrogen fertilizer and working it into the soil increased the percentage of No. 1's, total No. 1's and large No. 1's when compared with applying nitrogen in bands on each side of row at seeding (Figure 3). Some research has shown greater efficiency from banding (11) but our results agree with other research (9). Banding of nitrogen produced more growth cracks and culls (Figure 4). More tubers per potato plants resulted from banding and may explain the increased culls (small tubers). The average nitrate-nitrogen in potato petioles at early tuber set was greater from banded nitrogen, 29,323 ppm compared with 22,354 ppm on broadcast. This results in greater uptake of nitrate-nitrogen from banding but this effect appears undesirable for producing quality tubers. It suggests that part or all of the nitrogen should be broadcasted and worked into the soil prior to seeding.

Moisture

Moisture stress applied to potato plants at early tuber set (M1) increased the percentage of pointed stem end tubers, dumbbells and bottle-necked shaped tubers (Figure 5). Past research has shown these same effects (4 & 5). Yield and grade of tubers did not vary significantly between treatments where irrigations were applied when available moisture in soil

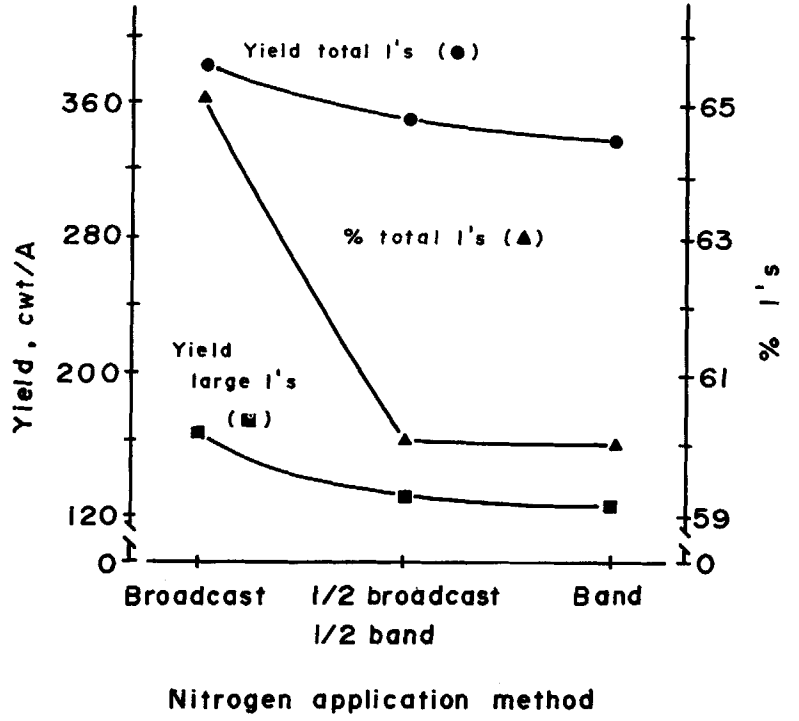

FIG. 3. Effect of nitrogen application on tuber yield and grade.

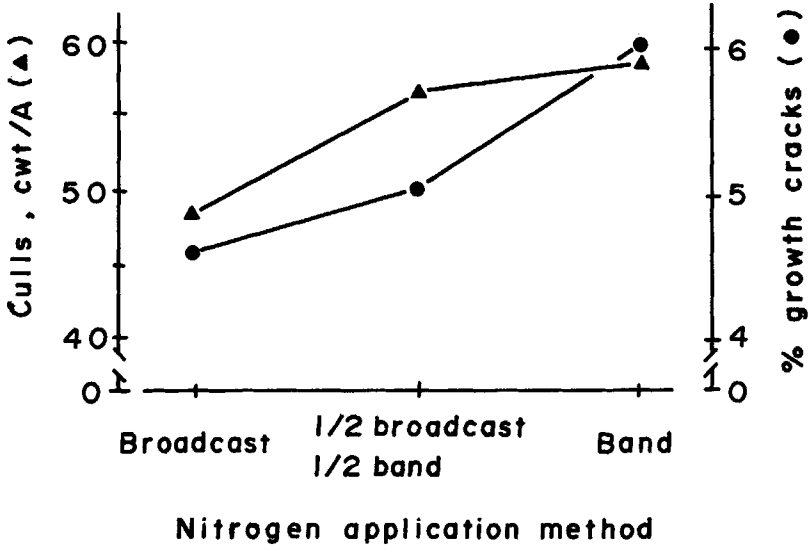

FIG. 4. Effect of nitrogen application on grade of tubers.

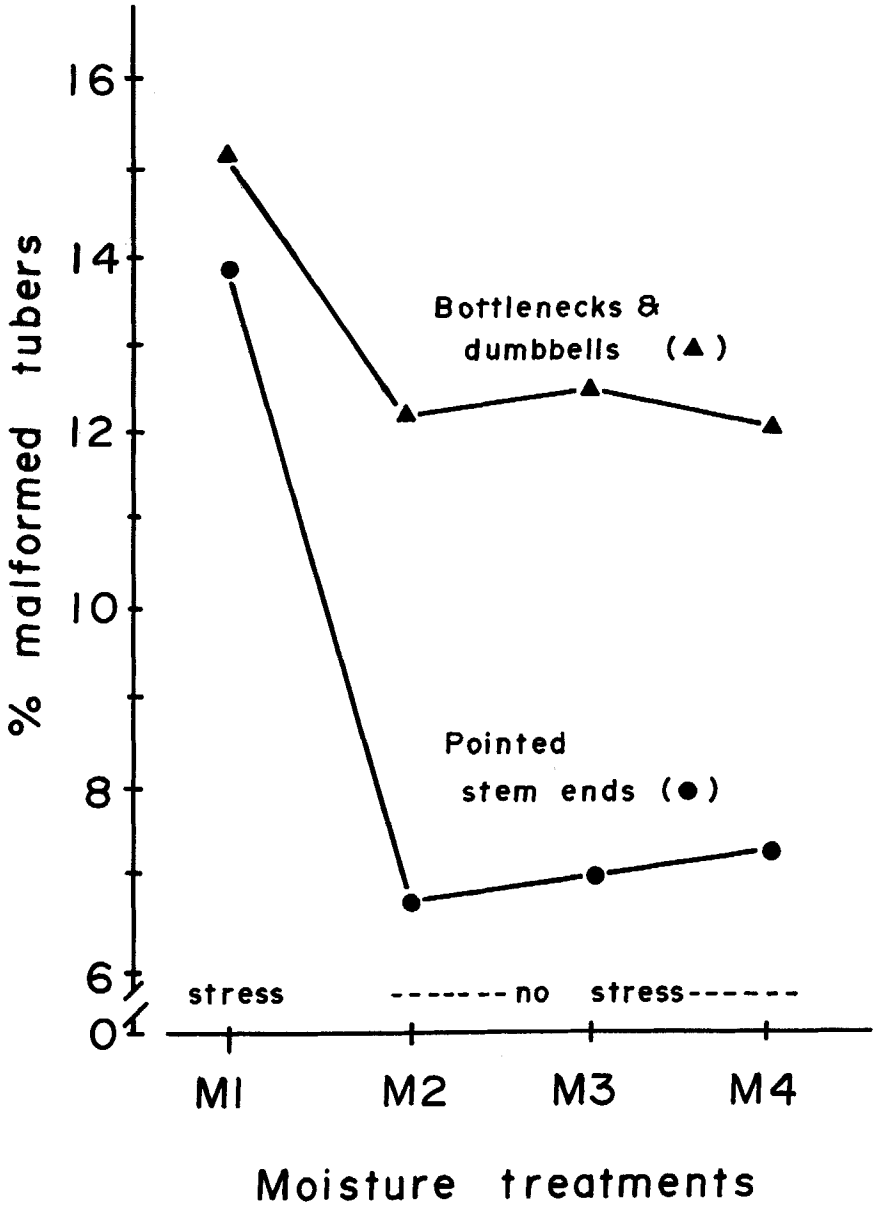

FIG. 5. Effect of moisture treatments on malformed tubers.

reached 65, 75, or 85 percent (moisture treatments M2, M3 and M4, respectively).

Moisture effects on tuber composition and quality are shown in Table 1. Increasing the available soil moisture from 65 to 85 percent prior to each irrigation during the growing season did not show any great differences between variables measured.

The conditions existing in 1972 were excellent for growing high quality tubers in southwestern Idaho. Soil temperatures were below normal. Effects of nitrogen rates and moisture variables on yield and quality of tubers were minor on both the research experiments and potato growers' fields.

Summary

1972 was an excellent year for producing high yield and quality tubers in southwestern Idaho. Total yield of tubers increased from 543 to 607 cwt per acre with increased nitrogen rates; but the percentage of tubers having malformations (pointed stem ends, bottlenecks, and dumbbells) also increased. The high nitrogen rates also reduced percent dry matter and ascorbic acid content and increased amino and total nitrogen in tubers. These types of malforms and quality compositions are associated with a lower grade of tuber for fresh marketing and a lower recovery and undesirable quality in processing.

Broadcasting and working the nitrogen fertilizer into the seed bed prior to planting produced less culls and growth cracks and more No. 1 tubers than where all the nitrogen was banded at planting time. Banding the nitrogen gave higher concentrations of nitrate-nitrogen in the potato petioles at early tuber set. This may indicate greater efficiency in nitrogen uptake but it was not desirable from a quality and grade evaluation.

Allowing available moisture depletion to 25 percent during the early part of the season, produced malformed tubers, which are undesirable for both fresh market and processing. Irrigating when available moisture in soil was above 65 percent did not affect yield or quality of tubers produced.

These data show that even during good years of potato production, stress applied to plants by low soil moisture levels or high nitrogen rates will reduce the grade and quality of tubers grown.

Literature Cited

1. Dow, A. I. 1957. Tests with potatoes. Wash Ext Circ 288.
2. Kunkel, R. 1966. Maximum yield of quality potatoes. Proceedings Annual PNW Fert Conf Wenatchee, Wash.
3. Kunkel, R. 1968. The effect of planting date, fertilizer rate and harvest date on the yield, culinary quality and processing quality of Russet Burbank potatoes in the Columbia Basin of Washington. Proceedings Annual PNW Fert Conf, Salem, Oregon.

4. Larsen, L. C. and R. E. Ohms. 1964. Timing of final irrigation for higher yield of number one potatoes. Idaho Current Information Series No. 2.
5. Nielson, L. W. and W. C. Sparks. 1953. Bottleneck tubers and jellyend rot in the Russet Burbank potato. Idaho Agric Exp Stn Bul 23.
6. Ohms, R. E. 1961. Malformed tubers. Idaho Agric Exp Stn Bul 340.
7. Painter, L. I. 1957. Fertilizer studies on Russet Burbank potatoes in Southern Idaho. Idaho Agric Exp Stn Bul 281.
8. Painter, C. G. 1970. The effect of planting dates, seed spacings, nitrogen rates and harvest dates on yield and quality of Idaho Russet Potatoes. Proceedings Annual PNW Fertilizer Conferences.
9. Painter C. G. 1973. Potato Fertilization in southwestern Idaho. Idaho Agric Exp Stn Prog Rep 167.
10. Sandsted, R. F. 1956. A survey of cultural practices affecting Idaho potatoes. Univ of Idaho Agric Exp Stn Prog Rep. Potato Investigations.
11. Viosh, Maurice L. 1971. Fertilizer studies with irrigated potatoes. Mich State University Farm Sci Res Rep 142.