WATER-NUTRIENT-HERBICIDE MANAGEMENT OF POTATOES WITH TRICKLE IRRIGATION[1]

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Abstract

A study was designed to test the effectiveness of nitrogen and herbicide applications through soil moisture-controlled, trickle-irrigation systems, and to test the effectiveness of automatic irrigation via soil moisture control to minimize the water requirement and N-losses for high-frequency, trickle-irrigation systems.

Results indicated that single or multiple applications of herbicide at recommended rates can be used effectively with trickle irrigation to control weeds in the potato row where cultivation is not possible. Nitrogen can be efficiently applied through a trickle system that features automatic soil moisture control through the use of a high-frequency irrigation schedule.

Resumen

Se diseñó un estudio para probar la efectividad de las aplicaciones de nitrógeno y herbícidas a través de sistemas de riego por goteo, con humedad controlada del suelo, y para probar la efectividad del riego automático a través del control de la humedad del suelo para disminuir los requerimientos de agua y las pérdidas de N por los sistemas de riego por goteo de altas frecuencias.

Los resultados indicaron que las aplicaciones simples o múltiples de herbicidas a las dosis recomendadas pueden usarse en forma efectiva con el riego por goteo para controlar las malas hierbas en las hileras de papa en donde no es posible cultivar. El nitrógeno puede aplicarse en forma eficiente mediante un sistema de goteo que equivale a un control automático de la humedad del suelo mediante el uso de un programa de riego de alta frecuencia.

Introduction

Post-emergence applications of herbicide to potatoes with conventional surface irrigation systems require large quantities of chemicals,

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which may not be distributed effectively. However, if herbicides are applied in a manner similar to trickle fertilization, herbicide placement on the crop row will be uniform and will better control specific weeds after plant emergence.

By irrigating frequently, water and nutrients were placed in the soil volume in which roots are most active (1, 2). Soluble fertilizers, applied through porous tubes with high-frequency irrigation, were distributed homogeneously in low concentration within the active root zone (2). Nutrient solution flux rates were high near the porous tube, and the nutrients became readily available to the plant after each irrigation. This is particularly important in humid regions where soluble N-fertilizer can be denitrified under anaerobic conditions or lost in runoff and/or by leaching after rainfall. Since the energy required to produce N-fertilizer represents a large portion of the total energy required to grow potatoes, potential methods for increasing the efficiency and effectiveness of fertilizer-N must be tested to determine optimum application rates.

Trickle fertilization can be optimized with a system based on high-frequency irrigation, rather than on concepts which use the soil for storage of water and nutrients. To accomplish this goal, water application must be controlled sufficiently to adjust for the complex seasonal and diurnal changes in crop fertilizer and water requirements (2). Controlling a high-frequency irrigation system accurately requires instrumentation to detect small changes in soil matric potential in the root zone, and to effectively provide only the amount of water required with minimum time lag to maintain an optimal, soil-matric-potential level. If this can be accomplished, the soil moisture can be maintained at an optimum level for N-mineralization and minimum denitrification and leaching losses.

This study was designed to test the effectiveness of herbicide applications through a trickle-irrigation system, to compare the N-uptake efficiency of trickle-fertilized vs. conventionally-fertilized potatoes with soil matric potential-controlled trickle irrigation, and to test the effectiveness of automatic irrigation via soil matric potential control to minimize the water requirement and N-losses for high frequency, trickle-irrigation systems.

Procedure

Potatoes (*Solanum tuberosum* L., cv Norchip) were grown on a Norfolk sandy loam soil (Thermic Typic Paleudults) with maximum and minimum rates of EPTC Herbicide (EPTAM 6E, Stauffer Chemical Corporation)[3]. Rates and times of application were as follows:

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[3]Trade names are used for identification purposes only and do not imply preference for this item by the U.S. Dept. of Agriculture.

Treatment Symbol	Method of EPTC Application	EPTC Product Applications (in kg/ha) on indicated Date and Julian Day. 4/4/75 94	4/24/75 114	5/9/75 129	6/3/75 154
TH_1	Trickle	6.72			
TH_2	Trickle	3.36	1.12	1.12	1.12
TH_3	Trickle	3.36			
TH_4	Trickle	1.68	0.56	0.56	0.56
C	Spray	6.72			

All treatments were replicated three times and each consisted of one single bed, 30 m long, using the twin-row-spacing configuration, described in detail earlier (1): Two rows of potatoes were planted 35 cm apart on each bed with a plastic, porous, irrigation tube installed on the bed between rows, and each bed was spaced 165 cm apart from center to center. The irrigation system consisted of a plastic, porous, tube-trickle irrigation system (Viaflo, E.I. duPont De Nemours & Co., Inc.)[3] installed 2 cm below the soil surface and connected to a 5-cm plastic layflat manifold. Design, installation, and operation of this trickle-irrigation system have been discussed previously (1, 4).

Herbicide (EPTC) was measured in a graduated cylinder diluted with water to a 500-ml volume, and applied with the irrigation water, according to the four TH treatments, and sprayed and incorporated 10 cm deep for the C treatment before planting. Weeds were identified and their population counted during the growing season.

Fertilizer solutions were applied several times each week at a rate of 250 ml/hr for all TH treatments. A complete fertilizer solution (10-20-10 analysis, Growers Corp.) plus an N solution containing 50% urea and 50% NH_4NO_3 were applied with the irrigation water to provide 180, 108, and 54 kg/ha each of N, P, and K, respectively. Time and rate of application of N are shown in Fig. 1. Additional P and K in granular form were banded between the twin rows at a rate of 112 kg/ha. Insecticide (diazinon) and nematocide (oxamyl-L) were metered through the tube every 15 days at a rate of 250 ml/hr.

For the C treatment, equal amounts of slow release N (Osmocote, 26% N), NH_4NO_3, and P and K fertilizers were broadcast on the bed to provide 224 kg/ha of N and 336 kg/ha each of P and K. Midway during the growing season, an additional 212 kg/ha of N was banded on each bed when petiole NO_3-N content in the C treatment indicated that N was below the 17,000 ppm and considered deficient (1). Pesticides were applied to the soil in the C treatment at rates equivalent to that in the TH_1 treatment.

Petiole NO_3-N, plant heights, potato yield, and quality, and the major elements in plant tubers were measured. Methods used for these measurements have been described previously (1).

A soil matric potential sensor and a solid-state rrigation controller (designed and constructed in cooperation with Watertech, now known as Moisture Control Systems, Inc.) were used to control the high-frequency irrigation system. The soil matric potential was measured hourly by the sensor-controller and the measurement was automatically used to determine the need for irrigation, based on the preset soil matric potential level. Concepts and application of this technique were previously published (2, 3). The period of irrigation was set at 15 min/hr, if the soil matric potential was lower than -200 mb. Water applied daily was recorded with a flowmeter (Rockwell, Model SR). Water deficit was calculated by subtracting rainfall from 80% of pan evaporation. Soil matric potential at the 15-cm depth was also measured manually with two tensiometers in each bed, at 10 and 20 m from the head of the plot and at a position and depth with respect to the row similar to that of the electronic sensor.

Results and Discussion

Potato yields, weed populations, and major element contents were not influenced by herbicide rates and timing of application within the TH treatments, except for the Ca content of the TH_1, which was lower (Tables 1, 2). The C treatment resulted in more total weight than TH_2 and TH_3 treatments, and more marketable weight than the TH_3 treatment. The weight of cracked tubers for the TH_2 treatment plots was lower than that for any treatment. For all TH treatments, the number of weeds on the bed was less than that for the C treatment (Table 1) and there seemed to be a trend indicating that multiple applications of EPTC through trickle irrigation systems may improve the control of weeds on the row.

Generally, neither the fertilization method nor herbicide application affected the major element content of the tubers, except for the P content

TABLE 1. — *Potato tuber yield (1975) as influenced by differential application rate and frequency of EPTC and N.*

Treatment	Weight	Marketable Weight*	Weight of Second Growth	Weight of Cracked Tubers	Percent of Marketable Weight	Number of Weeds on Bed
	kg/ha				%	1000/ha
TH_1	28740ab+	17471ab	912	409ab	61	153 b
TH_2	24731 b	17156ab	235	68 b	69	110 b
TH_3	24130 b	14028 b	623	274ab	58	145 b
TH_4	27125ab	17360ab	815	917a	64	75 b
C	32524a	24583a	494	302ab	75	427a

+Column values followed by the same letter are not significantly different at the 95% confidence level.

*Marketable weight is the total of US No. 1 and jumbo potatoes.

TABLE 2. — *Contents of major elements in potato tubers as influenced by fertilization and herbicide treatment.*

TREATMENTS	ELEMENTS				
	N	P	K	Ca	Mg
	%				
TH_1	1.68a*	0.38a	2.38a	0.024 b	0.097a
TH_2	1.64a	0.37a	2.40a	0.038a	0.097a
TH_3	1.66a	0.38a	2.52a	0.033a	0.083a
TH_4	1.57a	0.37a	2.61a	0.043a	0.097a
C	1.89a	0.46 b	2.52a	0.037a	0.100a

*Column values followed by the same letter are not significantly different at the 95% confidence level.

which was greater for the C treatment than for all TH treatments (Table 2), although the TH treatments received less than one-half of the fertilizers applied to the C treatment.

Mean petiole NO_3-N content for the TH and C treatments and the cumulative N-fertilizer applied as a function of time are shown in Fig. 1. Application of 180 kg/ha of N in solution, in small increments with the irrigation system throughout the growing season, was sufficient to maintain the mean petiole NO_3-N level above the recommended 17,000 ppm (1) until the end of the growing season.

The ratio of the petiole NO_3-N content to the applied fertilizer N as a function of time is shown in Fig. 2 for high-frequency trickle irrigation injected fertilization and conventional (banding) fertilization treatments. As seen in this figure, plants fertilized by high-frequency irrigation-fertilization techniques more effectively absorbed N per unit of N fertilizer applied than those conventionally fertilized.

Plant height measurements as a function of time are shown in Fig. 3. There were no differences in plant heights between the potatoes grown under the different treatments.

Cumulative water applied and the water budget as a function of time are shown in Fig. 4. The water budget and the water applied were identical at the end of the test and seemed to coincide within ± 2 cm during the test period. These results indicated that this method of water control is well suited for estimating irrigation requirements and for automating high-frequency trickle irrigation systems in particular when frequent rainfall is probable.

Mean soil matric potential of the treated plots as a function of time is shown in Fig. 5. These data are the mean of morning and afternoon tensiometric measurements obtained 10 and 20 m away from the head of the plots. When the system was set to maintain the soil matric potential around the controlling sensor at -200 mb, the mean soil matric potential throughout the field fluctuated between -50 and -300 mb, but the range of fluctuation

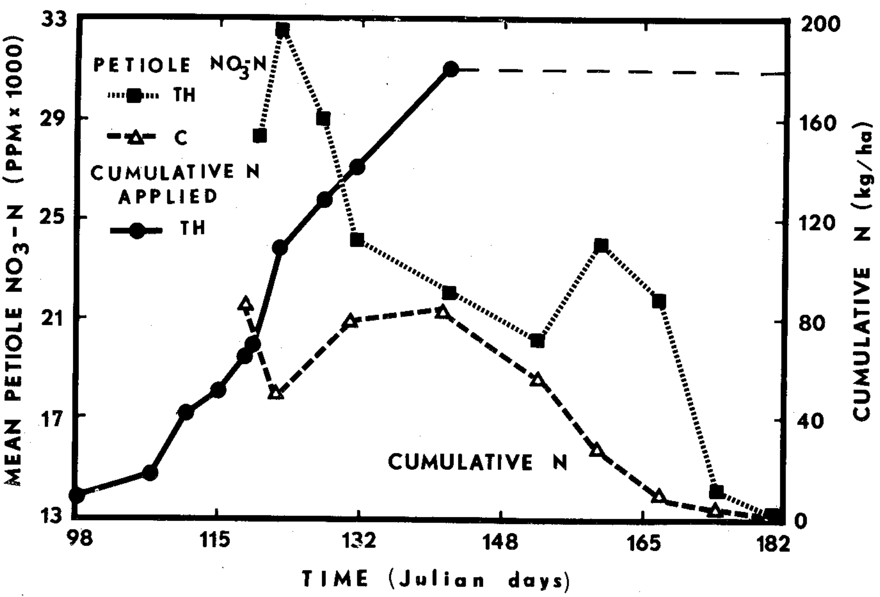

FIG. 1. Potato leaf petiole NO_3-N content and cumulative applied N-fertilizer for potatoes irrigated with high-frequency porous tube trickle irrigation system.

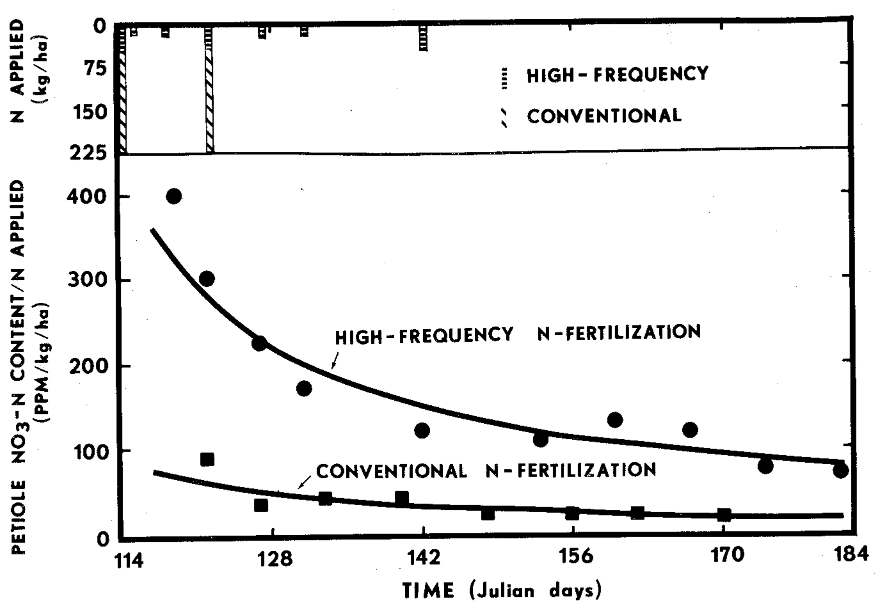

FIG. 2. Petiole NO_3-N content of potato leaf per unit of N applied for high-frequency and conventional N-fertilization methods.

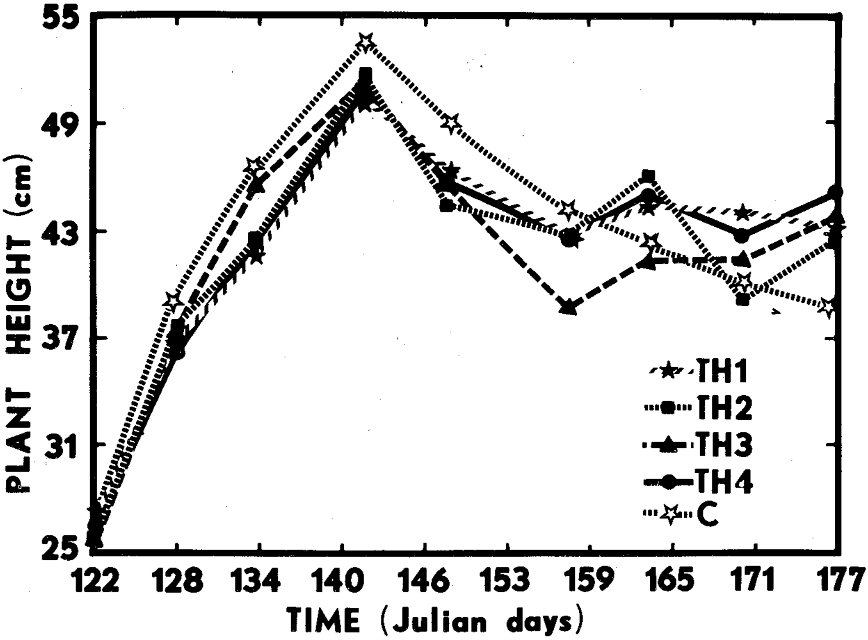

FIG. 3. Potato plant canopy as influenced by trickle irrigation, fertilization, and herbicides during the season.

was highly dependent upon the rainfall, as shown by the water deficit in Fig. 4.

The following weeds were identified: Lambsquarter *(Chenopodium album* L.), Goose Grass *(Eleusine indica* L.), Smooth Pigweed *(Amaranthus hybridus* L.), Ragweed *(Ambrosia artemisiifolia* L.), Carpetweed *(Mollugo verticillata* L.), Florida Pusley *(Richardia scabra* L.), Annual Sedge *(Cyperus compressus* L.). Weed population on the bed is shown in Table 1 and was more than 99% Annual Sedge. Between beds, where herbicides were not applied, weed population was 10 times greater than that on the row.

Potato yields in this test were comparable to those reported for Twin Row (TRI) Treatment in a previous test (1). However, evidence indicated that single or multiple applications of herbicide at recommended rates can be used effectively with trickle irrigation to control weeds in the potato row where cultivation is not possible. The yield differences between the TH and C treatments could have resulted from the difference in P and K application rates and/or from a difference in the mobility or availability of P, rather than from the herbicide application method. Future research is needed to refine the technique and to provide weed control data under controlled conditions that are not biased by fertility variables. Nitrogen applied through a trickle system can be used efficiently when soil moisture is controlled by high-frequency trickle irrigation.

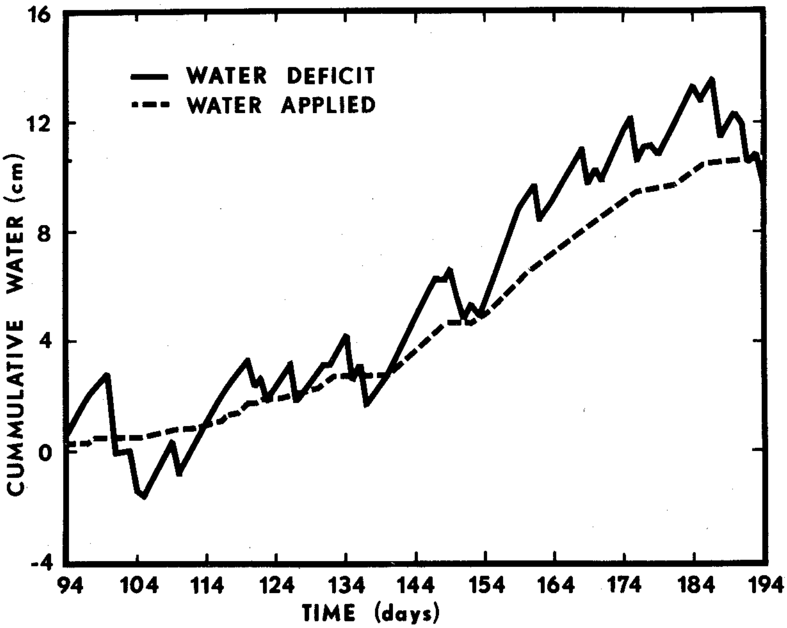

FIG. 4. Cumulative water deficit and irrigation water applied to potatoes by automated high-frequency trickle irrigation.

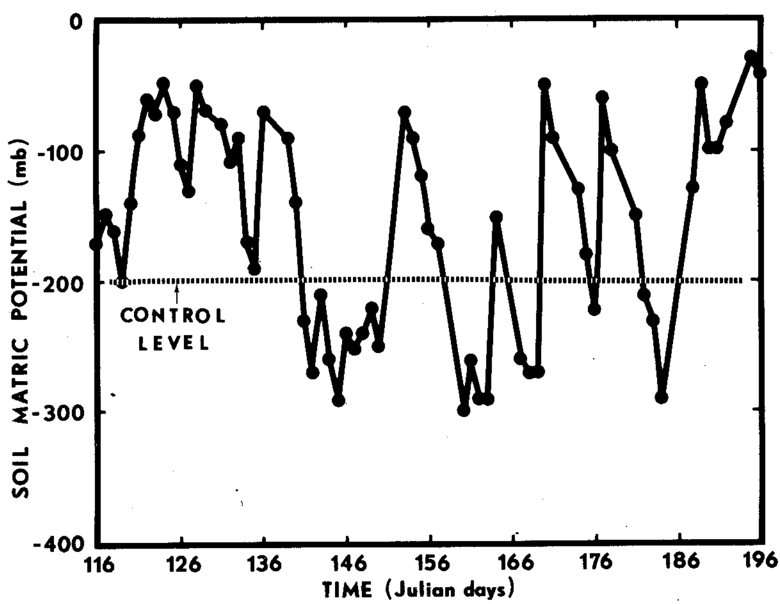

FIG. 5. Mean soil matric potential of treated plots with controlling sensor installed in one of the three replications and set to irrigate at -200 mb.

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