EFFECT OF RATE AND TIME OF FERTILIZATION ON NITROGEN AND YIELD OF RUSSET BURBANK POTATOES UNDER CENTER PIVOT IRRIGATION[1]

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Abstract

Applying less N on Russet Burbank potatoes (*Solanum tuberosum* L.) at planting time may reduce the potential loss of N from sandy soil by wind erosion and leaching early in the season. The objective of this study was to evaluate the effect of rate and time of N fertilization on potato production. Potatoes were grown in outdoor pot cultures with N rates of 75, 150 and 300 ppm and in field plots with N rates from 112 to 448 kg N/ha applied in single and split applications. The results from pot cultures harvested after one month's growth showed that yield of tops increased and tuber yield decreased as applied N at planting increased from 75 ppm to 150 or 300 ppm. Field results showed that the yield of potatoes was as high or higher when N applications were split between planting and when plants were 15 to 20 cm tall (early tuberization) as with the same amount of N applied at planting. Generally 112 kg N/ha at planting time was sufficient when additional N was applied after emergence. Split application of N resulted in more second growth on tubers than when all of the N was applied at planting.

Resumen

El aplicar menos N en papas de la variedad Russet Burbanl (*Solanum tuberosum* L.) al momento de la siembra puede reducir la pédida potencial de N en suelos arenosos debido a la erosión por viento y lixiviación temprana en la estación de cultivo. El objetivo de este estudio fué evaluar el efecto de la dosis y momento de fertilización nitrogenada en la producción de papas. Las papas fueron cultivadas en macetas en el exterior con dosis de 15,150 y 300 ppm de N, y en parcelas en el campo con dosis de 112 a 448 kg N/ha, en una aplicación o en parcialidades. Los resultados de los cultivos en macetas después de un mes de crecimiento mostraron un aumento de la producción de partes aéreas de la planta y reducción del rendimiento cuando el N aplicado en la siembra aumentó de 75 ppm a 150 o 300 ppm. Los resultados de campo mostraron que el rendimiento de la papa fué similar o

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mayor cuando las aplicaciones de N fueron divididas entre el momento de la siembra y cuando las plantas tenían 15 a 20 cm de altura (tuberización temprana) que al aplicar la misma cantidad de N solo al momento de la siembra. En general, la dosis de 112 kg/ha al momento de la siembra fué suficiente cuando una aplicación suplementaria de N fué aplicada dispués de la emergencia. La aplicación parcializada de N resultó en mayor proporción de tubérculos con crecimiento secundario que al aplicar todo el N en la siembra.

Introduction

Potatoes (*Solanum tuberosum* L.) irrigated by center-pivot or solid set sprinklers usually receive split applications of N fertilizer with a portion of the N at planting and the rest as incremental injections into the sprinkler water during the growing season. Splitting the N application instead of applying all of the fertilizer at planting time on sandy soil limits the amount of N exposed to early-season wind erosion and possible leaching while getting a crop established (11, 12, 13, 14). Growers are urged to utilize crop residue to keep fertilizer and soil from blowing away at the peak of the windy season from planting to crop emergence instead of using excessive irrigation which causes leaching (14). As a general guideline Iritani (8) suggested applying about half of the N at planting to insure a uniform set of tubers, and then using frequent light applications of N the rest of the season to maintain vegetative growth and rapid bulking of tubers.

In Canada an increase in marketable potatoes resulted from applying part of the N at planting and the rest when plants were 25-cm tall as compared with applying all of the N at planting (5). In solution culture Krauss (10) found earlier tuberization with low N than with high N concentrations. According to Sattelmacher and Marschner (13) phytohormones in potatoes which control tuberization are activated by the combined effects of N nutritional status of plants, day length, and temperature.

Information is needed on the feasibility of minimizing the potential loss of N from sandy soil early in the season by cutting back the application of N at potato planting time and applying more N later during the peak N demand of the crop. The objective of this study was to evaluate the effect of rate and time of N fertilization on early growth and tuberization of potatoes in pot cultures and on yield and grade of potatoes grown in the field.

Materials and Methods

Pot Cultures— Potatoes (*Solanum tuberosum* L. var. 'Russet Burbank') were grown outdoors in polyethylene-lined pots that were inserted in metal cylinders buried at ground level. Each pot contained 15 kg of air-dry Ritzville fine sandy loam. The soil was collected from an undeveloped area and contained only 2 ppm residual NH_4 – and NO_3 – N. Potatoes were cut in 50-g seed pieces which were placed in a potting mix for a month to obtain shoots 5 cm long. A single seed-piece was transplanted to each pot on June 12. The pot culture soil was passed through a 2-mm sieve, mixed with $Ca(H_2PO_4)_2$, K_2SO_4 and $ZnSO_4$ to give 75 ppm P, 100 ppm K and 10 ppm Zn, respectively. A solution containing NH_4NO_3 was added to the surface of the soil at designated times (Table 1) to give N rates of 75, 150 and 300 ppm based on the air-dry weight of soil. Pot cultures were treated with N either at planting

TABLE 1. - *Effect of rate and time of applying N on Russet Burbank potatoes in pot cultures showing N percentage in plant tops (dry weight basis), total N uptake in tops and tuber for harvest 3 and tuber count per pot averaged for three harvests.*

N applied	N concentration in plant tops at three harvests			N uptake	Tubers/ pot
	1(July 15)	2(July 25)	3(Aug. 4)		
ppm		%		g/pot	
		N at planting, June 12†			
75	2.7a	1.7a	1.4a	1.4a	21 b
150	3.7 b	2.3 b	1.6ab	2.4 b	20 b
300	5.1 b	3.7 d	2.2 c	4.3 c	24 b
		Split application of N‡			
75	3.5 b	2.2 b	1.7 b	1.4a	18ab
150	4.2 c	2.6 bc	1.7 b	2.4 b	23 b
300	4.9 d	3.6 d	2.2 c	4.5 c	24 b
		N at tuber development, July 9			
75	4.7 d	2.7 c	1.8 bc	1.3a	12a
150	4.9 d	3.9 d	2.0 c	2.5 b	12a
300	4.8 d	5.3 e	3.3 d	4.2 c	12a

†Values within columns without a common letter are significantly different at 5% probability using Duncan's multiple range test.
‡Split with one-third at planting June 12 and the rest at tuber development July 9.

(June 12), at tuber development (July 9) or in a split application with one-third of the N at planting and the rest at tuber development. Soil moisture in the pots was maintained near 20% by an automated drip irrigation system. Additional hand watering was done on alternate days to restore pot weights to the original moisture level. All treatments were randomized and replicated 12 times.

Potato tops and tubers were harvested from four replications of treatments on July 15 and from four additional replications at 10 and 20 days thereafter. The fresh weight and number of tubers and oven-dry (70°C) weight of tops and tubers were determined, and the dried plant tissue was ground to pass a 20-mesh screen. Total Kjeldahl N was determined in plant tissue (1), and total N uptake was calculated.

Field Experiments—A three-year field study in the lower Yakima Valley with Russet Burbank potatoes involved different N rates in single and split applications. One experiment irrigated by solid-set sprinklers was conducted on Hezel loamy sand at Roza Unit II of the Prosser Irrigated Agriculture Research Center (Table 2). Two other experiments were conducted on Quincy loamy sand irrigated by center pivots. Results from only one of the center pivot experiments are fully reported (Table 2). None of these sites had produced potatoes before, and residual inorganic N was low with only 5 ppm NO_3-N (about 20 kg N/ha) or less to a depth of 60 cm.

TABLE 2. — *Effect of rate and time of nitrogen application on Russet Burbank potatoes grown on Hezel loamy sand irrigated by solid-set sprinklers and on Quincy loamy sand with center pivot irrigation.*

N applied at			U.S. No. 1		U.S. No. 1 & 2	Petiole NO_3-N on	
Planting kg/ha	Post-emergence kg/ha	Yield T/ha	T/ha	%	%	June 15 %	July 15 %
		Solid-set (sidedress N) experiment†					
112	0	58.9a	38.1 b	65 bc	84ab	1.1 b	0.3a
224	0	65.9 b	52.2 c	79 c	91 b	1.6 c	0.8 b
448	0	68.1 b	50.0 c	73 c	92 b	2.0 c	1.9 d
0	224 (June 7)	68.8 b	42.3 b	62 b	89 b	1.2 b	1.4 c
0	224 (June 18)‡	53.3a	24.2a	45a	79a	0.1a	0-1.a
		Center pivot (broadcast N) experiment)§					
112	0	67.4a	47.2 b	70 c	-	1.8a	1.5a
224	0	69.2ab	49.1 b	71 c	-	2.1a	1.6a
336	0	67.9a	42.8ab	63 b	-	2.6 b	1.9 b
112	224 (June 7)	77.5 b	44.2ab	57ab	-	2.8 b	2.3 bc
112	224 (July 9)	73.7ab	38.1a	52a	-	1.9a	2.5 c

†Values within a column of each experiment without a common letter are significantly different at 5% probability using Duncan's multiple range test.

‡Half of the N was broadcast June 18 and the rest was broadcast in four equal applications every 2 weeks thereafter.

§All center pivot N treatments had extra 224 kg N/ha as incremental injection into sprinkler water from mid-June to mid-August.

Russet Burbank potatoes were planted in mid-April in rows spaced 86-cm apart with seed pieces spaced 23-cm in the row. The N treatments indicated in Table 2 were replicated five times in a randomized block design in plots each four rows wide by 12 m long. Urea was sidedressed in the solid-set sprinkler experiment and NH_4NO_3 was applied broadcast in the center pivot experiments to obtain the N treatments. The rates of other nutrients (P, K, S and Zn) were based on soil tests (6). An adequate level of available soil moisture was maintained with high frequency irrigation on a daily or alternate day schedule during the season. Recommended pesticides were used for control of insects and weeds. Tissue samples consisting of a composite of 24 petioles from the fourth or fifth leaf from the tops of the plants were collected from each plot twice during the season. Samples were oven dried at 70°C, ground to pass a 20-mesh screen in preparation for potentiometric determination of NO_3 (2). Potatoes were harvested from a 10-m section of two center rows of each plot, graded, and weighed for determining fresh-weight yield.

Results and Discussion

Nitrogen Response in Pot Cultures — Potatoes in pot cultures showed some notable treatment effects due to applying different rates of N at planting time, at tuber development or as a split treatment with part of the N added both times. The yield of plant tops over three successive harvests showed consistent increases as the N rates at planting increased from 75 to 300 ppm (Fig. 1, 2, 3). Increasing the N rate at planting resulted in a steady decrease in fresh weight of tubers at harvest 1, a mixed response at harvest 2 and a steady increase in yield of tubers at harvest 3. The fresh tubers averaged 19 to 20% dry matter with no effect of N treatments on dry matter content.

Split applications of 150 and 300 ppm N (with one-third at planting and the rest at tuber development) resulted in reduced yield of tops and significantly higher tuber yields in harvest 1 than did these same N rates at planting (Fig. 1). Split application of N on potatoes in Israel also reduced the amount of top growth and maximized tuber yield as compared with applying all of the N at planting (3). When no N was applied until after tuberization, tuber yields were lowest for all three harvests even though top growth caught up by the third harvest (Fig. 1, 2, 3). The primary reason for the depressed tuber yield with this method of application was depressed tuberization (Table 1). Thus it appears that a limited amount of available N is desirable initially to stimulate tuberization. A similar reduction in potato yield was reported from a field study where no N fertilizer was applied until 24 days after crop emergence (7). Sattelmacher and Marschner (13) found that high N nutrition depressed tuberization, but they probably used higher N rates than we did. Table 1 shows no depression in tuberization with increased N rates.

Chapman (4) reported critical N levels from separate experiments ranging from 3.8 to 6.3% N in total tops of 60-day-old White Rose potatoes. Most of the plant N concentrations in harvest 1 of our study were within this critical N range, and none of our plant N values exceeded the upper limit of the cited critical range (Table 1). The highest at-planting N-rate limited the tuber bulking rate initially, but did not limit tuberization as indicated by the number of tubers (Table 1). There was also some depression in bulking with the high rate of N on the second and third harvests when all of the N was applied late (Fig. 2, 3). This coincided with high levels of N in the tops in the late harvests (Table 1), and rapid foliar growth between the second and third harvests (Fig. 2, 3).

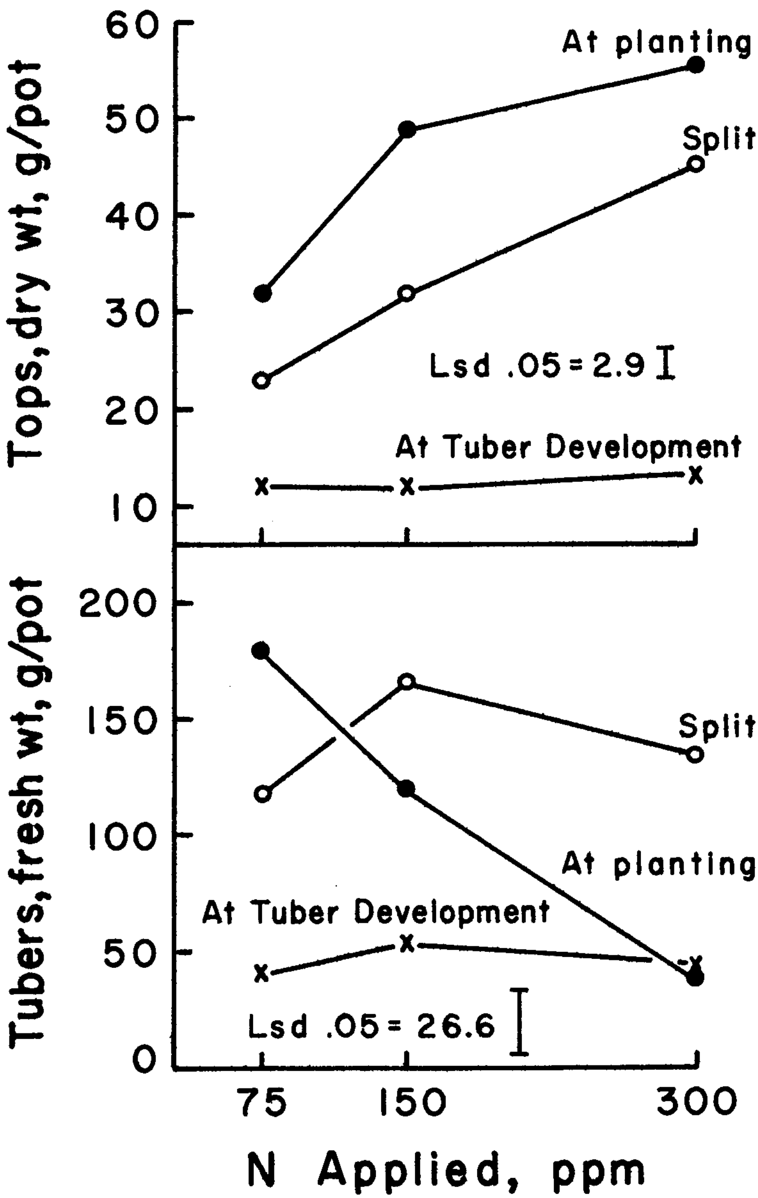

FIG. 1. Harvest 1: Yield of dry matter in tops and fresh weight of tubers for potatoes in pot cultures, July 15.

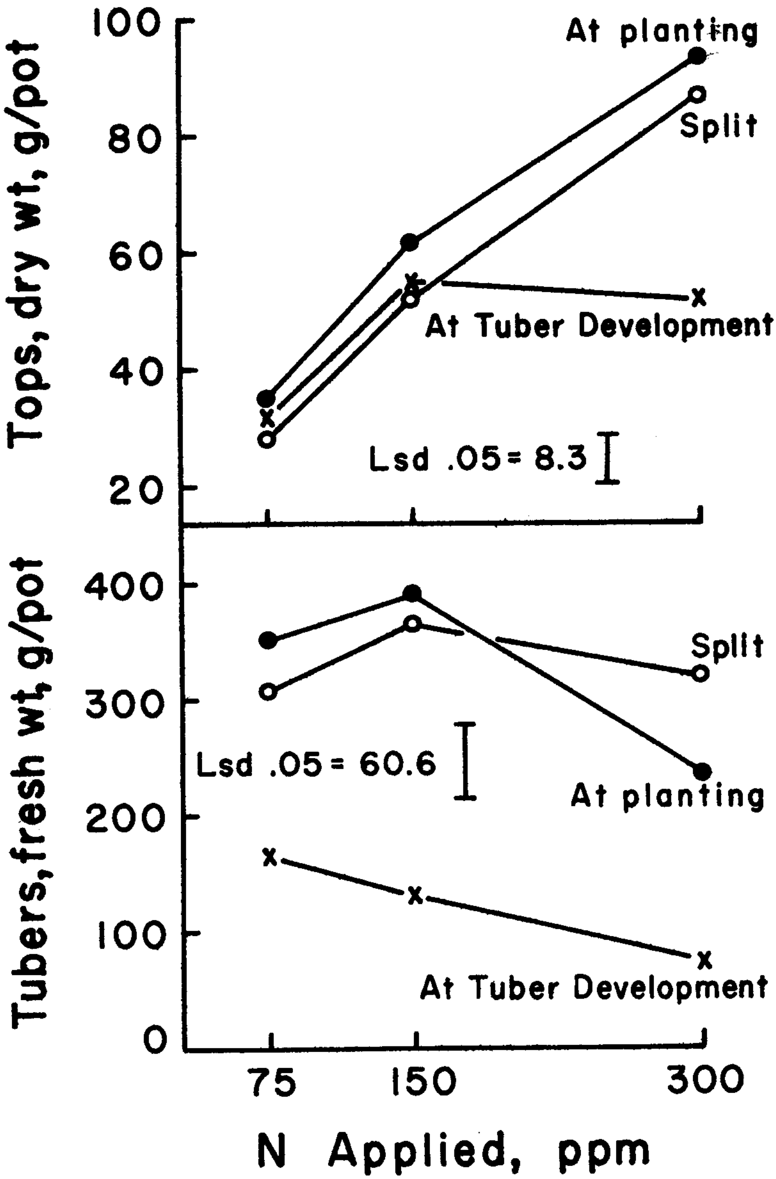

FIG. 2. Harvest 2: Yield of dry matter in tops and fresh weight of tubers for potatoes in pot cultures, July 25.

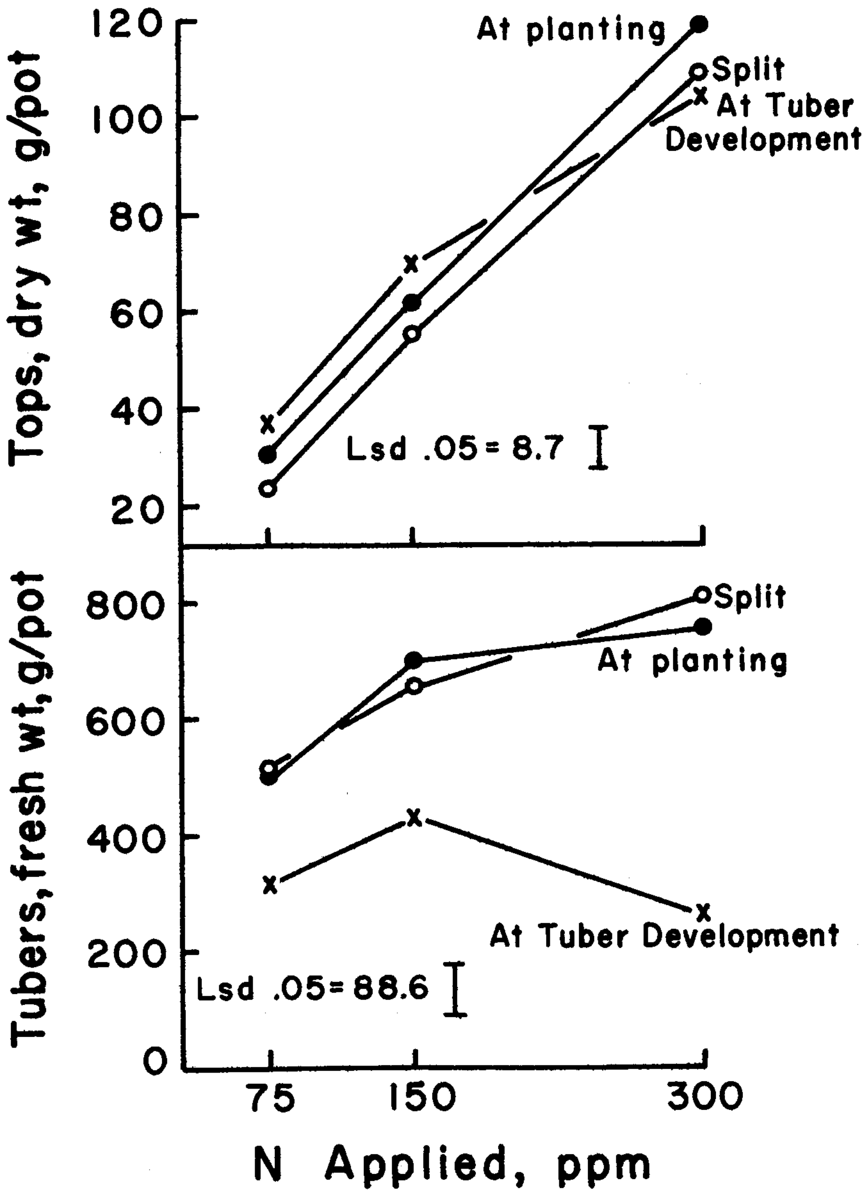

FIG. 3. Harvest 3: Yield of dry matter in tops and fresh weight of tubers for potatoes in pot cultures, August 4.

Tuber numbers increased very little from one harvest to the next and the number of tubers per pot averaged from all three harvests increased significantly in nearly all cases with N at planting as compared with N applied at tuber development. Sometimes high N fertility suppresses tuberization (13), but this may require over 300 ppm N which was applied here.

Nitrogen Response in the Field — In the solid-set sprinkler experiment the total tonnage of potatoes approached a maximum with 224 kg N/ha applied either at planting or as post-emergence treatment June 7 (Table 2). Relying entirely on an early (June 7), post-emergence N fertilization decreased the yield of No. 1 potatoes as compared to fertilization at planting, although the total yield was not significantly affected. Both total tonnage and yield of No. 1 tubers were significantly depressed with a longer delay in N fertilization. The post-emergence N resulted in an increase in malformed tubers that dropped the grade from U.S. No. 1 to No. 2 (Table 2). This would not affect the return for saleable processing potatoes but does represent a loss for a fresh-market crop of No. 1 potatoes.

A center pivot experiment was conducted primarily to evaluate possible changes in the early-season fertilizer schedule that might help minimize potential N loss by wind erosion and leaching (Table 2). The season total N applications were not too important because following a prescribed growth period after treatment the entire plot area received an additional blanket application of 224 kg N/ha distributed in small increments at frequent intervals in sprinkler water (see footnote Table 2).

The total tonnage of potatoes under center pivot was not increased significantly by increasing at-planting N rates from 112 kg N/ha to 336 kg N/ha (Table 2). Applying 336 kg N/ha reduced the yield of U.S. No. 1 potatoes significantly as compared with lower N rates which produced less second growth and fewer off-type tubers. Split-N application has proven beneficial at times for overcoming detrimental yield effects of applying too much N at planting (3). When 336 kg N/ha was split between planting and early June, total tuber yield was significantly higher than when the entire amount was applied at planting. As in the solid-set study the late application of a heavy N rate (224 kg/ha) resulted in increased second growth on tubers. Thus the yield of U.S. Grade No. 1 was not improved by split N application.

Jones and Painter (9) placed the critical level for potato petioles in the range of 1.8 to 2.2% NO_3 at early tuber set which is about the first part of June in our area. Applying 224 and 448 kg N/ha under solid-set and all N applications under center-pivot sprinkler gave nearly adequate levels of petiole NO_3 on June 15 and close to maximum yields of potatoes (Table 2). Split-N applications between planting and the first week of June gave significantly higher petiole NO_3 in July than a like amount of N applied at planting in both experiments (Table 2). It was interesting that N applied in several increments after June 18 in the solid-set experiment gave a low N nutritional status of plants with only 0.1% petiole NO_3-N on both sampling dates and also reduced the yield of potatoes.

These results show little yield increase with more than 224 kg N/ha in the solid-set experiment or 336 kg N/ha in the center-pivot experiment with 112 kg N/ha at planting and the rest in sprinkler water. Leaching was probably minimal because excessive irrigation was not needed for control of wind erosion which was less severe than usual at these sites. It can be concluded that 112 kg N/ha at potato planting time is adequate to meet crop needs on these sandy soils until the first of June. Additional N may be applied in June after the windy season is over and at a time approaching the peak N demand by the crop. Besides limiting the exposure of N to wind erosion or leaching there was no great advantage in making split applications of N. The latter point may require additional research.

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