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Nitrogen Rate and Timing Effects on Onion Growth and Nutrient Uptake in a Subtropical Climate

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ABSTRACT

Nitrogen application is necessary for onion (*Allum Cepa L.*) production in subtropical, semiarid South Texas; however, fertilizer N uptake efficiency is low. This study was conducted to identify onion growth and nutrient uptake patterns in order to base fertilizer practices on a more basic understanding of crop need. Onion growth followed a bimodal pattern growing very slowly for the first 100 days then shifting to a rapid growth phase. This growth pattern was affected primarily by cultivar and very little by timing or rate of N application. Nitrogen application readily enhanced N uptake, with increases in plant N concentration following N application in some cases occurring quickly, and in some cases lasting for up to 4 months depending on weather conditions. Timing of N application had a greater effect on yields than rate applied, but which was the best application timing again depended on climatic conditions. In the dryer, warmer year, preplant and winter applications produced the highest yields while in the wetter, cooler year, winter and spring applications gave the best results. The winter application (early December) produced the best yields under both dryer-warmer and wetter-cooler conditions. Where yield responses to N application occurred, application of N at rates greater than 84 kg N ha^{-1} usually gave no additional yield benefit. While this study confirmed the clear need for N fertilizer application, uptake efficiency of applied N continued to be disappointingly low averaging less than 10%, with very little improvement likely to occur using the optimum timing and rate of application developed in this study.

RESUMEN

La aplicación de nitógeno es necesaria para la producción de cebolla (*Allium cepa L.*) en la región subtropical y semiárida del sur de Texas; sin embargo, la eficiencia de absorción de este elemento es lenta. Este estudio se realizó para identificar los patrones de crecimiento y de la incorporación de nutrientes en cebolla, para fundamentar las prácticas de fertilización sobre un conocimiento más básico de las necesidades del cultivo. El crecimiento de la cebolla siguió un patrón bimodal con crecimiento muy lento durante los primeros 100 días cambiando después a una fase de crecimiento rápida. Este patrón de crecimiento fue afectado primariamente por el tipo de cultivar y muy poco por el tiempo o la dosis de la aplicación de nitrógeno. La aplicación de nitrógeno aumentó rápidamente la incorporación de este elemento, presentándose incrementos en la concentración de nitrógeno en la planta después de la aplicación, algunas veces rápidamente y en otros casos tardando hasta 4 meses dependiendo de las condiciones climáticas. Los rendimientos fueron mayormente afectados por el calendario de aplicación del nitrógeno que por la dosis aplicada, pero la determinación del mejor calendario dependió también de las condiciones climáticas. En el año más seco y más caliente, las aplicaciones antes de la siembra e invernales produjeron los rendimientos más altos, mientras que en el año más frío y más húmedo, las aplicaciones en el énvierno y en la primavera dieron los mejores resultados. La aplicación en invierno (a principios de diciembre) produjo los mejores rendimientos tanto en las condiciones más secas-más calientes como en las más húmedas-más frías. En los casos en que ocurrieron respuestas en el rendimiento debido a la aplicación de nitrógeno, la aplicación de dosis mayores que 84 kg/ha usualmente no dio ningún beneficio adicional. Mientras que en este estudio se confirmó la clara necesidad de la aplicación de fertilizante nitrogenado, la eficiencia de la absorción del nitrógeno aplicado continuó siendo decepcionablemente baja promediando menos del 10%, con muy poca mejoría probablemente debido al uso del calendario y de la dosis óptima de aplicación desarrolladas en este estudio.

Nitrogen fertilizer is required for onion production in subtropical South Texas, however, the rate needed and the method of application are less clearly established. Recommendations typically range between 134 and 202 kg N ha^{-1} with the fertilizer split into as many as 5 or 6 applications with most of the N being applied during the period of rapid growth in the spring (Longbrake et al., 1987; Pennington & Thompson, 1982). However, the available research studies support only more moderate N application rates (Gausman et al. 1953; Wiedenfeld 1986), and split applications with the last part of the N being applied no later than thinning (December in South Texas).

Uptake efficiency of applied N typically ranges between 15 and 30% (Wiedenfeld & Braverman 1991) with the remainder wasted and potentially contributing to water pollution. Strategies to improve fertilizer uptake such as optimization of rate, improved placement, or slow-release materials have met with limited success (Wiedenfeld 1986, Wiedenfeld & Braverman 1991). Widely used soil tests do not take into account mineralization, a major source of N in a subtropical environment. Climatic conditions also vary considerably between growing seasons.

Another possible approach to improve fertilizer uptake efficiency is to base fertilizer practices on a more basic knowledge of the crop's growth patterns and nutrient

Table 1. Statisical significance of N treatment effects on onion yields for three cultivars in two growing seasons.

year	effect	Y33	502	1015
		cultivar		
1990-91	block	***	**	-
	timing (T)	***	***	***
	rate (R)	-	-	-
	T x R	-	-	-
1991-92	block	*	*	*
	timing (T)	***	***	***
	rate (R)	-	L^s	L^{**}
	T x R	-	*	-

Differences are significant at the .10(^{s}), . 05 (*), .01 (**), or .001(***) level. For continuous variables, significant treatment effects were linear (L).38

requirements over time. Such physiological patterns are understood in a general way for all crops, but are less well established for cool season crops in a subtropical environment, and may vary with annual fluctuation in the climate. Growth typically begins slowly during the cool winter months, then accelerates during bulb formation. It seems reasonable to delay fertilizer application to this rapid growth phase when the N is most needed. However, preplant or applications of N made early during growth have often been found to be more effective (Wiedenfeld 1988). The crop may not be able to take up all the N that it needs during the most rapid phases of growth even though enough is available in the soil, or the N applied later may not be accessible to the roots because of where it was placed.

This study was conducted to determine the effect of rate and timing of N application on onion growth and nutrient uptake patterns over time and onion yield.

MATERIALS AND METHODS

Field studies were conducted at the Texas A&M University Agricultural Research and Extension Center at Weslaco for two seasons on a Hidalgo sandy clay loam soil. Preplant soil tests conducted by the Extension Soil Testing Laboratory, Texas Agricultural Extension Service, College Station, TX (Donohue 1992) showed very low NO^3-N(5.1 ppm); very high P, K, Ca, Mg and micronutrients; no salinity hazard, organic matter content of 1.3% and pH of 8.5. The area has a subtropical, semiarid climate.

Treatments consisted of application of N fertilizer at 0, 84, 168 and 252 kg N.ha^{-1}, and three different timings-preplant (1 day prior), winter, and early spring (5 December and 18 February the first year; and 10 December and 24 January the second year). Treatments were replicated 4 times in randomized block designs each year for each of three cultivars - an early (Y33), a mid-season (TG502Y), and a late (TG1015Y). Plots were 6.1 m wide consisting of six rows spaced 1 m apart and were 7.6 or 9.2 m long. Fertilizers were applied in bands below and to the side of

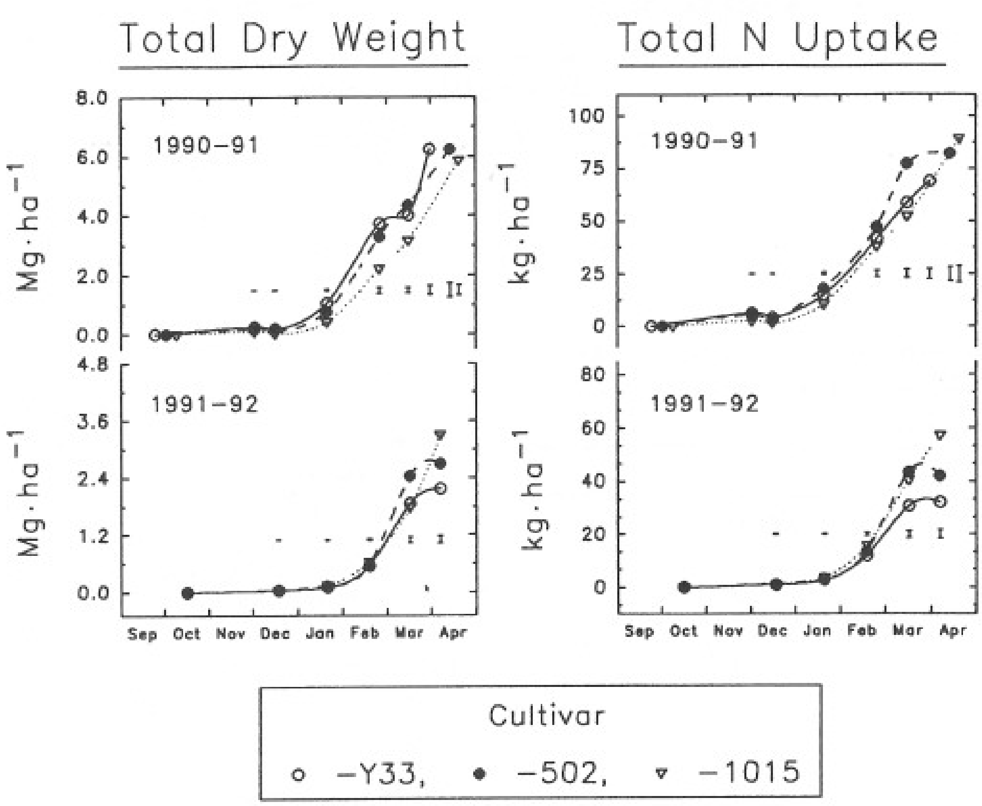

Fig. 1. Onion total dry weight accumulation and total N uptake over time for three onion cultivars during two crops. Error bars represent the standard error or the mean.

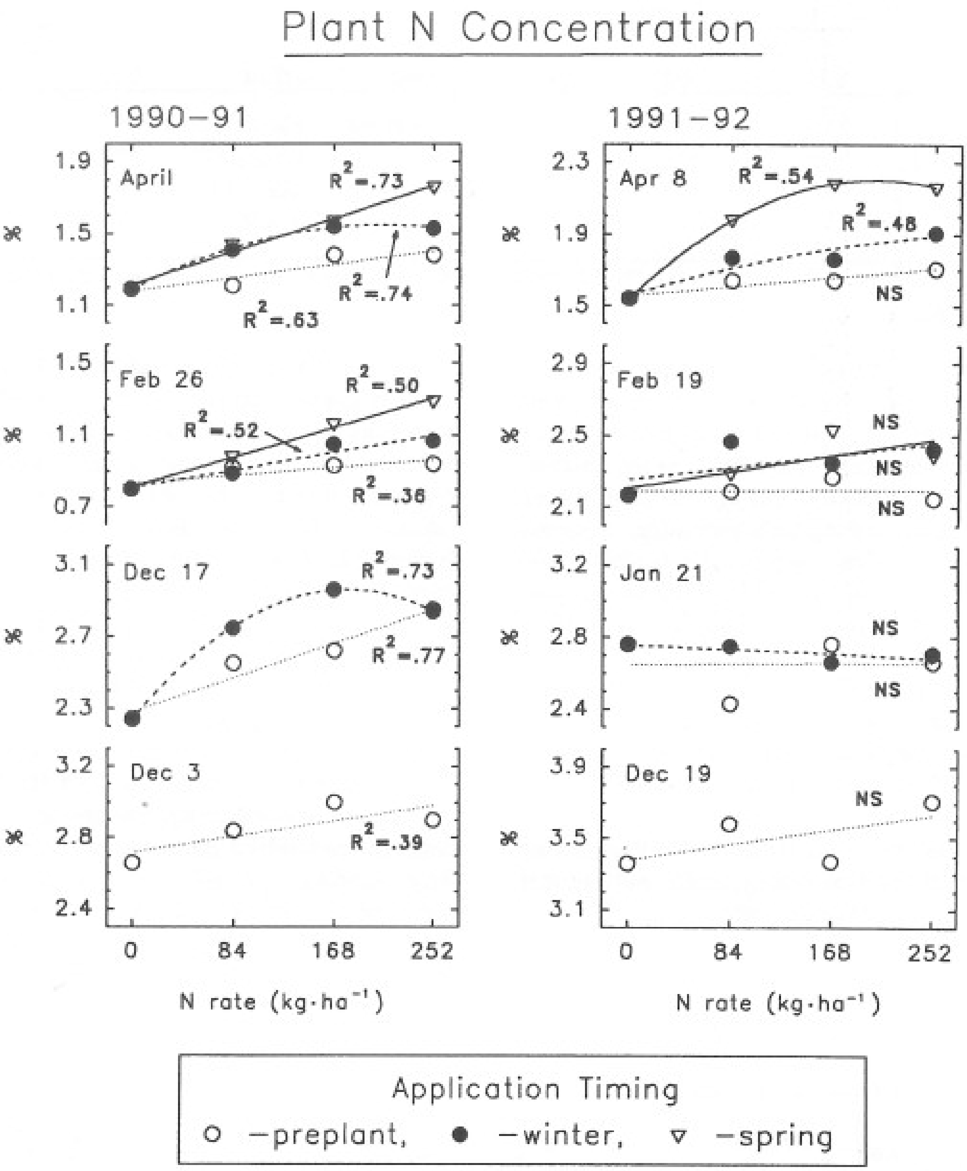

Fig. 2. Effect of N application rate at different application timings on onion plant N concentration on several different dates during two seasons. Values are averages for three cultivars.

Table 2. Nitrogen fertilizer uptake efficiency relative to an unfertilized check for different timing and rate of N application for 2 onion crops.

	crop	
	1990-91	1991-92
timing	----- % -----	
preplant	6	7
winter	7	11
spring	13	12
N rate (kg ha^{-1})		
84	9	12
168	9	10
252	7	8

Means were not significantly different.

the seed row as liquid UAN (32-0-0, 1/2 urea-N, 1/2 NH_4NO_3-N).

Onion crops were grown with cultural practices used commercially in South Texas. The land was prepared into raised beds, and the onions were planted direct seeded, double row with 25 cm between rows on each bed. Planting dates were 26 September, 4 October and 11 October for the three cultivars in 1990; and all three cultivars were planted on 17 October (due to wet weather) in 1991. Water was applied as required using furrow irrigation, the water coming from the Rio Grande River and having an average electrical conductivity of 0.16 Sm^{-1}. The 1990-91 and 1991-92 crops received 95 and 302 mm of rainfall and 6 and 5 irrigations, respectively; with approximately 100 mm of water applied at each irrigation. The onions were thinned by hand to a 7 - 8 cm in-row spacing in December or early January. Weed control was accomplished mechanically and with

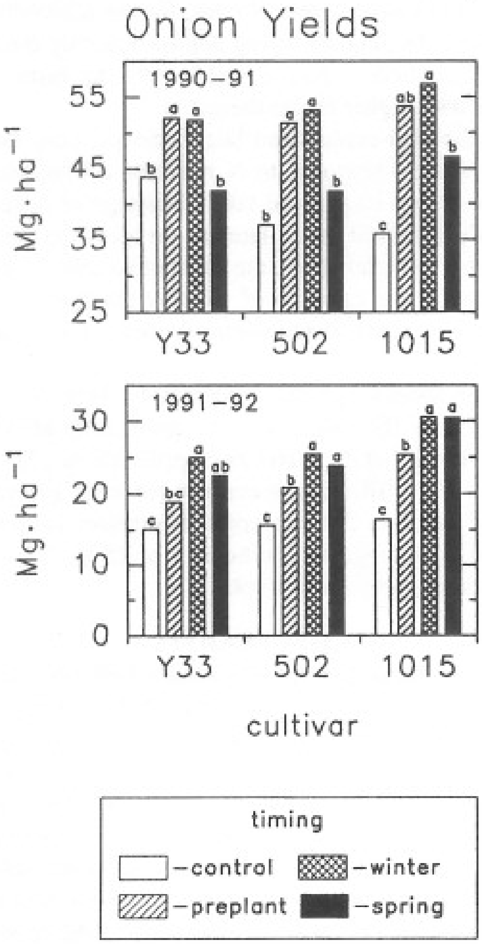

Fig. 3 Yield of three onion cultivars in two growing seasons as affected by timing of fertilizer application. Mean comparisons were made for each cultivar each season using Duncan's multiple range test at the 5% level.

herbicide [bensuilide (Prefar, ICI)], purple blotch was controlled with fungicides [metalaxyl + chlorothalonil (Ridomil Bravo, Ciba Geigy) and mancozeb (Dithane, Rohm & Haas)], and thrips were controlled using insecticides [methomyl (Lannate, Dupont), azinphos-methyl (Guthion, Mobay) and cypermethrin (Ammo, FMC)].

Plant growth and nitrogen uptake were measured over time, and onion yield was determined by size class at harvest. Plant samples were randomly selected from the 2nd and 5th rows in each plot at intervals during growth, the number of plants depending on plant size. When plants were small, whole plant samples were taken, and after bulbs began forming samples were divided into leaves and bulbs. These plant samples were oven dried and weighed, then ground and analyzed for N concentration using a wet acid digestion and a Wescan® Ammonia Analyzer. Plant populations were determined both before and after thinning. Yields were determined by harvesting and trimming all onions from the middle two rows of each plot. The onions were divided into three size classes, counted, and weighed. All data were analyzed statistically using the GLM procedure of the SAS software system for data analysis which allows continuous and discrete variables in the same model (SAS Institute Inc. 1988).

RESULTS AND DISCUSSION

Onion growth, as indicated by total dry weight accumulation, was slow after planting for all three cultivars in both seasons (Fig. 1). In the later part of January onion growth rate increased substantially. Differences in growth occured due to cultivar after the onset of the rapid growth phase, with the earlier maturing cultivars growing at a faster rate, particularly in the first year when they were planted earlier. The early maturing cultivar then tended to cease growth sooner, probably a result of a physiological response to day length or temperatures. Statistically significant differences in growth due to N fertilized timing and rate occurred at many of the sampling dates, but the differences were small relative to the total amount of biomass that was being accumulated during this rapid growth phase, and also often tended to be temporary (data not shown).

Changes in total N uptake over time followed the same pattern as did total dry weight, with very slow uptake from planting until the later part of January, then much more rapid uptake from that point until crop maturity (Fig. 1). Nitrogen uptake seemed to be of greater importance in the early growth phase since about 8% of the crop's final N uptake had occurred by late January, while about 4% of the final biomass had accumulated by that point in time. Nitrogen concentration in plant tissue tended to decline with crop age, as occurs with most other crops. However, even though N uptake relative to biomass accumulation declined after mid-January, over 90% of the N uptake occurred during the later, rapid growth phase.

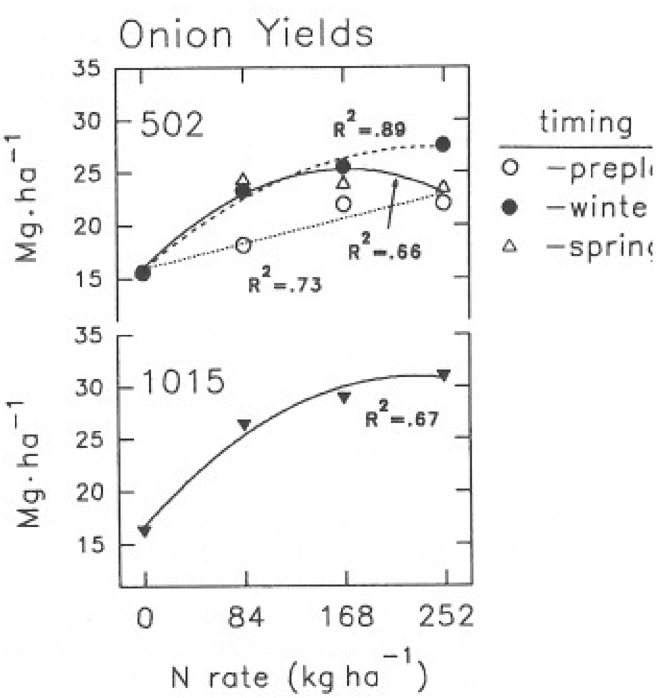

Fig. 4. Yield of two onion cultivars in the 1991-92 growing season as affected by rate of N application. For cultivar 502 a significant (P=.05) interaction occurred between rate and timing of application.

Increasing N application resulted in increased plant N concentration. Nitrogen applied preplant in the 1990-91 crop in late September and early October had a statistically significant effect on plant N concentration at all sampling dates from 3 December through April (Fig. 2). This effect indicated a very long-lasting effect of fertilizer N in the soil. Also in the 1990-91 crop, the winter fertilizer application on 5 December had a significant effect on plant N concentration on the 17 December sampling, and the spring fertilizer application on 18 February had a significant effect on plant N concentration on the 26 February sampling. This shows that plant uptake of N occurred soon after application of fertilizer.

In the second season, rainfall was three times greater than in the previous season and probably influenced the effect of N application on plant N concentration. Preplant N application on 16 October showed no effect on plant N concentration on 19 December, or on any sampling date thereafter (Fig 2). Heavy rainfall had occured in October after planting. In this second crop, the winter fertilizer application made on 10 December was not evident in plant N concentration on 21 January, and did not have significant effect until 8 April. Similarly, the early spring application made on 24 January caused no increase in plant N concentration until 8 April. Growth in this second crop was substantially lower overall than in the previous year due to cooler, wetter weather, and this could have been responsible for the delay in the response of plant N concentration to the winter and spring fertilizer N applications.

Onion yields were significantly affected by timing of fertilizer application on all cultivars in both seasons, and by fertilizer rate on two of the three cultivars in the second season (Table 1). All yield differences were a result of differences in onion size since no statistically significant differences in onion number among treatments were found. In the first crop, highest yields were consistently obtained for the preplant and winter applications on all three cultivars (Fig. 3). For the early and mid-season cultivars (Y33 and 502, respectively), yields for the spring fertilizer application were no different than the unfertlized control. This occurred even though this spring N application had quickly increased plant N concentration in all cultivars (Fig. 2). Spring fertilizer application on the late cultivar increased yields over the unfertilized control, but not as much as for the preplant and winter applications. This cultivar grew longer and therefore had more time to take advantage of this late N application, but not enough to compensate for the benefits from the preplant and winter applications. In the second season yields for all three cultivars were highest for the winter and spring fertilizer asspplications, with the preplant application giving yields greater than the unfertilized control but not as high as the later two application dates (Fig. 3). Weather conditions (both rainfall amount and distribution; and cooler temperatures) probably influenced this different annual response to timing of fertilizer application. Rate of N application affected yields of the late-maturing cultivar 1015, and had an interactive effect with timing of application on the mid-season cultivar 502 (Fig. 4). For this cultivar, increasing the N rate had a linear effect on yield for the preplant and a quadratic effect, or smaller increases in yield at higher N rates, for the winter fertilizer applications; but for the spring application only the lowest rate of N applied increased yields, with no further yield increases with higher N rate thereafter.

Since the mid-season and late cultivars were the ones showing a yield response to N rate, the conditions under which the onion crop could take advantage of N fertilizer apparently occurred much later in the growing season in this second crop; however, the interactive effect with timing still raises the question of whether the spring application was as effective as the winter application in enhancing yields.

Nitrogen fertilizer uptake efficiency for both crops averaged less than 10% and was not significantly affected by timing or rate of N fertilizer application (Table 2). Although N fertilizer is necessary for crop growth, the increased biomass that the applied fertilizer caused only contained on average an additional 8 to 25 kg N ha^{-1} compared to the unfertilized control.

CONCLUSIONS

Onion growth and N uptake patterns followed a definite bimodal pattern over time regardless of the climatic conditions, and this pattern varied primarily with maturity class of the cultivar. Total growth, however, was strongly influenced by climatic conditions, and to a much lesser degree by nutrition. Nitrogen application resulted in increased N uptake as reflected in plant N concentrations, and these effects could appear quickly after application and persist for very long periods of time, again depending on weather conditions. Yield responses to N application were primarily due to timing of application, however patterns were not consistent from one season to another. The superiority of the preplant and winter application timings in one season, and the winter and spring application timings in the other season again show the effect of climatic conditions on fertilizer N availability. However, N application took much longer to affect yields than to affect plant N concentration. Even though climatic conditions varied considerably from one season to the other, the winter fertilizer application timing (early December) gave yields among the best in both years. While plant N concentrations increased with rate of N applied, best yields were obtained in most cases in response to fertilizer application only, with no effect due to rate of N applied, indicating that the lowest rate was usually adequate. While this study confirmed the need for N fertilizer application, uptake efficiency of applied N continued to be disappointingly low, with very little improvement probable using the optimum timing and rate of application developed in this study.

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