FERTILIZER RATE AND TYPE IMPACTS MAGNOLIA AND OAK GROWTH IN SANDY LANDSCAPE SOIL

by Edward F. Gilman[1], Thomas H. Yeager[2], and Donald Kent[3]

Abstract. Southern magnolia *(Magnolia grandiflora)* planted as 3-L (1-gal) liners into sandy soil did not respond to nitrogen applications above 20 g N/m^2 (4.2 lb N/ 1,000 ft^2) per year the first 2 years after planting. The 40 g N/m^2 (8.3 lb N/1,000 ft^2) per year rate resulted in greater height than the 20-g (4.2-lb) rate in the third year and greater height and trunk diameter the fourth year after planting. Nitrogen rates greater than 40 g N/m^2 did not result in more growth. Seedling magnolia and 10- to 13-cm (4- to 5-in.) caliper field-grown live oak *(Quercus virginiana)* trees receiving nitrogen soon after transplanting responded the first year of application by growing faster than those that received no nitrogen. Nitrogen source had little impact on growth or tissue nitrogen concentration (1.4%) of 10- to 13-cm-caliper live oak in the first 3 years after field transplanting, and there was no N source effect on root extension from the trunk. All fertilizers containing nitrogen promoted growth. Nitrogen applications increased trunk growth on 23-cm (9-in.) caliper live oak beginning about 16 months after transplanting with a tree spade. Potassium and/or phosphorus, when applied in conjunction with nitrogen, had no effect on growth.

Key Words. Transplanting; nitrogen, potassium; phosphorus.

Nitrogen is typically soil applied to evoke a shoot or root growth response in trees (Jacobs 1930; Chadwick et al. 1957; Neely et al. 1970; van de Werken 1981; Watson 1994). Hensley et al. (1988) and Schulte and Whitcomb (1975) found that nitrogen applied to the soil at planting resulted in more growth than trees receiving no nitrogen the first year after planting. However, there are numerous reports of recently transplanted trees not responding to nitrogen (Shoup et al. 1981; van de Werken 1981; Whitcomb 1981; Wright and Hale 1983; Khatamian et al. 1984; Ponder et al. 1984; Gilman and Yeager 1990). Established trees have responded to nitrogen applications (Neely et al. 1970; van de Werken 1984) or not responded (Perry and Hickman 1998). Watson (1994) determined that root growth increased in response to nitrogen application, but Warren (1993) determined that root growth was suppressed at high nitrogen concentrations.

Trees generally have not responded to applications in excess of 14 to 24 g N/m^2 (3 to 5 lb N/1,000 ft^2) per year (Conover and Joiner 1974; van de Werken 1984; Gilman and Yeager 1990; Ingram et al. 1998), although there are examples of increased tree trunk and shoot growth with nitrogen rates up to 49 g N/m^2 (10 lb N/1,000 ft^2) per year (Klein et al. 1988). Application of phosphorus and potassium to the root zone of established trees seldom proved beneficial (Neely et al. 1970; van de Werken 1981; Watson 1994).

In addition to the rate of application, the fertilizer type and placement of the fertilizer may influence plant growth response. Van de Werken (1981) determined that slow-release fertilizers resulted in taller sugar maple *(Acer saccharum)* trees with larger trunks and broader canopies than trees receiving ammonium nitrate, whereas Gilman (1987) determined that plants were larger when fertilized with slow-release N compared to urea fertilizer. Other studies (Chadwick et al. 1957; Conover and Joiner 1974; Gilman1987; Gilman and Yeager 1990; Ingram et al. 1998) have revealed that organic, slow-release, inorganic, liquid, or granular fertilizers resulted in similar tree growth response. Broadcast fertilizer applications, compared to placing fertilizer below the soil surface, resulted in enhanced growth of trees (Chadwick et al. 1957; van de Werken 1984), whereas others showed that method of fertilizer application did not effect tree or shrub growth (Jacobs 1930; Neely et al. 1970; Hensley et al. 1988; Gilman 1989). No studies showed more growth from subsurface application than from broadcast surface application.

The following experiments were conducted to determine 1) if nitrogen application rate or fertilizer type influenced tree growth rate in sandy soils, 2) if transplanted large trees respond to fertilizer application the first year after transplanting, and 3) if phosphorus and/or potassium applications caused a growth response in trees after transplanting.

MATERIALS AND METHODS

Nitrogen Rate

Two-hundred-forty seedlings of Southern magnolia (*Magnolia grandiflora* L.) were selected for uniformity from a group of approximately 500 plants and planted from 3-L (1-gal) plastic containers on 2.4-m (8-ft) centers into a Myakka Varient fine sand soil with a pH of 6.1 to 7.0 February 1987 in central Florida (USDA hardiness zone 9). Soil tests revealed K_2O at 12 ppm K and P_2O_5 at 84 ppm. Trees were arranged in a randomized complete block design with 5 trees per treatment per block in 8 blocks for a total of 40 trees per treatment. The 5 trees were positioned between 2 buffer trees at the end of each row. The treatments were 6 application rates of nitrogen applied as ammonium nitrate: 0, 20, 40, 60, 80, and 100 g N/m^2 (4.2, 8.3, 12.4, 16.5, and 20.6 lb N/1,000 ft^2) per year divided into 9 equal applications. Ammonium nitrate was surface applied to a 0.9-m (3-ft) diameter circle monthly February through October each year for 4 years after planting beginning March 1987 and ending February 1991, and dolomitic limestone was surface applied at 112 g/m^2 (1,000 lb/ac) once each year. Muriate of potash at 9.3 g K_2O/m^2 (83 lb/ac) was broadcast at planting and applied every spring around each tree in a 0.9-m (3-ft) diameter circle. The water table fluctuated between 0.3 and 0.9 m (1 and 3 ft) below the surface during the study, so trees were not regularly irrigated after they were planted. Weeds were periodically controlled with oryzalin and glyphosate in a 0.9 × 0.9 m (3 × 3 ft) square around each plant. Vegetation between trees was periodically mowed. Trees were root pruned with a shovel 20 cm (8 in.) deep February 1988 in a 30-cm (12-in.) diameter circle around the trunk. This mimics the practice many nurseries carry out to improve root branching in the root ball.

Tree height and trunk diameter, at 15 cm (6 in.) above soil line, were measured at planting and at the end of each growing season. T-tests were used to evaluate equality of slopes of growth curves with $P < 0.05$ significant. One-way analysis of variance in a randomized complete block design with 5 replications/treatment was used to compare growth data means.

Fertilizer Type

Sixty-six nursery-grown live oak (*Quercus virginiana* L.) with 11- to 12-cm (4- to 5-in.) trunk diameters, measured 30 cm (12 in.) above soil surface, were dug with a 1.5-m (60-in.) diameter tree spade and moved about 65 m (200 ft) in March 1987 to the same site as described above. Trees were planted 6.1 m (20 ft) apart on a berm about 30 cm (1 ft) above surrounding soil and mulched with a 8-cm (3-in.) deep layer of cypress (*Taxodium distichum* L. Rich.) wood chips in a 1.8 × 1.8 m (6 × 6 ft) square around the trunk. The berm facilitated flood irrigation. Trees were periodically irrigated the first 5 months by flooding the swale between berms. Irrigation water did not cover the mulch placed around each tree. Beginning in May 1987 and continuing through June 1990, 11 trees received each of the following fertilizers in a randomized complete block design: 2 applications per year (May and November) of Milorganite (6 N-2 P_2O_5-0 K_2O) (Milwaukee Metropolitan Sewage District, Milwaukee, WI), 2 applications per year (May and November) of Nutricote 180 (16 N-10 P_2O_5-10 K_2O) (Plantco, Inc., Ontario, Canada), 1 application per year (May) of Nutricote 360 (16 N-10 P_2O_5-10 K_2O), 2 applications per year (May and November) of Osmocote (18 N-6 P_2O_5-12 K_2O) (Scotts-Sierra Horticultural Products Company, Marysville, OH), and 9 applications per year (March through November) of ammonium nitrate (33.5 N - 0 P_2O_5 - 0 K_2O). Fertilizer was surface applied at 29.3 g N/m^2 (6 lb N/1,000 ft^2) per year to a 1.8 × 1.8 m (6 × 6 ft) mulched area around each trench until May 1989, when the application area was increased to 3.7 × 3.7 m (12 × 12 ft). Because the rate remained the same at 29.3 g N/m^2 (6 lb N/1,000 ft^2) per year, the amount of fertilizer applied per tree increased fourfold in May 1989 due to the fourfold increase in application area. Eleven control trees received no fertilizer. Trees were not root pruned after they were transplanted.

Trunk diameter 30 cm (12 in.) from the ground was recorded at the beginning of the study and semiannually. Tissue nitrogen content was determined from a composite sample of recently expanded leaves from the outer portion of the canopy on 2 trees per treatment in October 1991. The 10 largest-diameter roots at the edge of the original 1.5-m (60-in.) diameter root ball were excavated and followed to their end in June 1990. The distance along the root from the root tips to the trunk was recorded for 2 trees per treatment. T-tests were used to evaluate equality of growth curves with $P < 0.05$ significance.

One-way analysis of variance in a randomized complete block design was used to analyze growth data.

N:P:K Ratio

One-hundred-sixty live oaks nursery grown in sand soil in central Florida near Orlando (USDA hardiness zone 9) with 23-cm (9-in) trunk diameters were transplanted into Pomello fine sand soil on 6.1-m (20-ft) centers in June 1994 using a 2.2-m (90-in.) diameter tree spade and irrigated regularly to keep them vigorous. Soil tests revealed K_2O at 12 ppm K and P_2O_5 at 84 ppm. Beginning the following March (1995), 32 trees received 1 of the following 5 fertilizer treatments at 4.9 g N/m^2 (1 lb N/1,000 ft^2) per application every other month through July 1996: a $N:P_2O_5:K_2O$ ratio of 2-1-1, 2-0-1, 2-0-0, 2-1-0, and a nonfertilized control. Fertilizer carriers were ammonium nitrate, muriate of potash, and superphosphate. Fertilizer was surface applied to a 3 × 3 m (10 × 10 ft) square centered around each trunk. Treatments were arranged in a randomized complete block design with 1 replicate of each treatment in each of 32 blocks. Trunk diameter was recorded in May 1995 then periodically until September 1996. T-tests were used to evaluate equality of growth curves with $P < 0.05$ significance. One-way analysis of variance in a randomized complete block design was used to analyze growth data.

RESULTS AND DISCUSSION

Nitrogen Rate

Southern magnolia that did not receive nitrogen applications increased in size in each of the 4 years after planting from 3-L (1-gal.) containers (Figure 1). However, trees receiving nitrogen grew in height faster than controls, beginning in the year of application. Except for the first year after planting for the 20 g N/m^2 (4.2 lb N/1,000 ft^2) rate, trunk diameter (data not shown) and tree height (Figure 1) for all rates in all years increased more than controls. Hensley et al. (1988) also found that southern magnolia seedlings responded to nitrogen in the year of application; however, van de Werken (1981) found that several other species, including sugar maple, of recently planted trees did not respond until 2 to 3 years after application.

Nitrogen rates above 20 g N/m^2 (4.2 lb N/1,000 ft^2) per year did not result in increased tree height or trunk diameter the first 2 years after application and could increase N leaching past the root zone. In the third and fourth year after application, tree height for the 40 g N/m^2 (8.3 lb N/1,000 ft^2) rate was significantly greater than for the 20 g N/m^2 (4.2 lb N/1,000ft^2) rate, resulting in taller trees for the 40 g N/m^2 (8.3 lb N/1,000 ft^2) rate at the end of the 4-year study (Figure 1). Trees receiving 80 g N/m^2 (16.5 lb N/1,000 ft^2) also were taller than those receiving the 20 g N/m^2 (4.2 lb N/1,000 ft^2) rate. The 40 g (8.3 lb N/1,000 ft^2) rate resulted in significantly larger trunk diameter than the 20 g N/m^2 (4.2 lb N/1,000 ft^2) rate in the fourth year after fertilizer application. This concurs with other studies

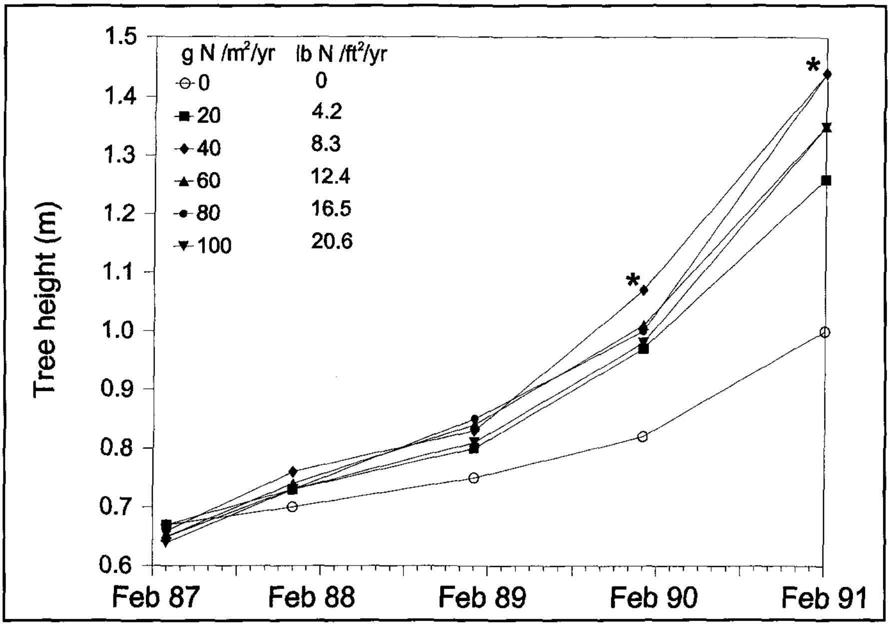

Figure 1. Trunk diameter 4 years after planting southern magnolia from 3-L (1-gal) containers and fertilized with different rates of nitrogen.

that revealed no increase in growth or tissue nitrogen concentration from applying more than about 24 g N/m^2 (5 lb N/1,000 ft^2) per year (Ponder et al. 1984; Ingram et al. 1998; Perry and Hickman 1998).

Fertilizer Type

Eleven- to twelve-cm (4- to 5-in.) caliper live oak trees fertilized with ammonium nitrate, Nutricote 180, and Nutricote 360 grew more than the nonfertilized controls the first year after transplanting (Figure 2). All fertilized trees grew at similar rates the second and third year, and all grew faster than nonfertilized controls in the third year. Live oak tissue nitrogen concentrations (1.4%) were not affected by fertilizer. Ingram et al. (1998) also found little effect of fertilizer on tissue nitrogen content. Other studies (Gilman and Yeager 1990; Ingram et al. 1998) revealed that the source of nitrogen had little or no influence on tree growth. Neither the phosphorus nor the potassium in the slow-release fertilizers (Milorganite, Nutricote, Osmocote) resulted in a measurable growth response compared to trees receiving only ammonium nitrate. Fertilizer type had no impact on root extension from the trunk.

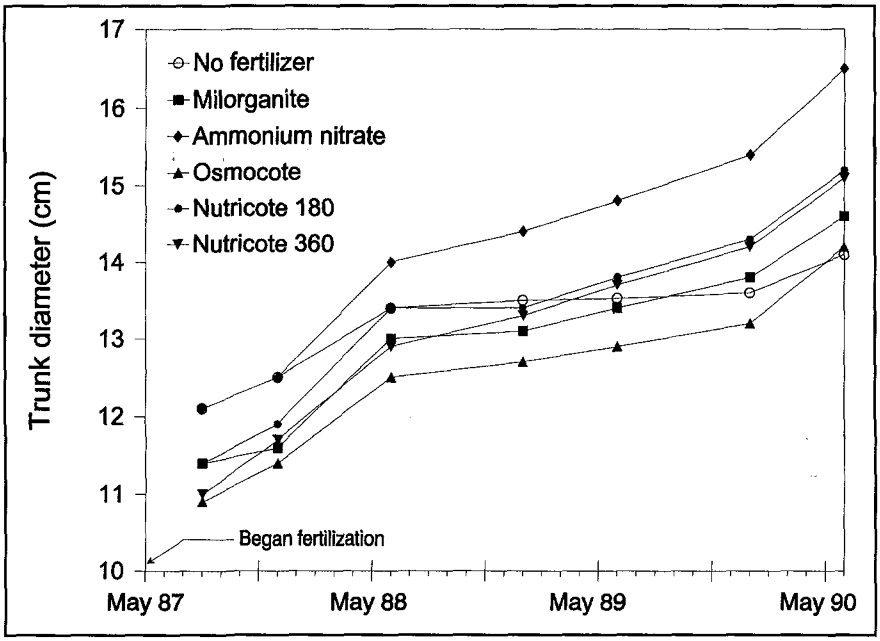

Figure 2. Trunk diameter for 3 years after transplanting live oak receiving 5 different sources of nitrogen fertilizer.

The large trees in this study responded to fertilizer the first year, whereas in other studies with trees close to this size no response was observed (van de Werken 1984). This may have occurred because establishment rate is much faster in USDA hardiness zone 9 than in the hardiness zones where the other studies were conducted (Gilman and Beeson 1996). Recently planted trees that are not established generally do not respond to nitrogen applications (Wright and Hale 1983; van de Werken 1984). Establishment takes from 3 months (in hardiness zone 9) to about 12 months (in hardiness zone 5) per inch of trunk caliper (Gilman and Beeson 1996).

N:P:K Ratio

All fertilized trees grew at the same rate regardless of the N:P:K ratio applied (Table 1). Fertilized 23-cm (9-in.) caliper live oak trees grew at the same rate as nonfertilized controls for the first 5 months after applying fertilizer (9 to 13 months after transplanting). During the next 12 months (14 to 26 months after transplanting), fertilized trees, except for the 2-1-0 treatment, grew slightly (significant at $P < 0.03$) faster than nonfertilized controls. Trees should have been established by this time according to Gilman and Beeson (1996), who predicted that irrigated trees of this size should take about 24 months to become established.

CONCLUSIONS

1. Addition of fertilizer was not necessary for survival or growth of seedling southern magnolia and 10- to 23-cm (4- to 9-in.) caliper live oak in the first 3 to 4 years after transplanting.
2. Applying more than 40 g N/m^2 (8.3 lb N/1,000 ft^2) per year resulted in no increase in growth for southern magnolia over a 4-year period.
3. Seedling southern magnolia and 10- to 13-cm (4- to 5-in.) caliper live oak trees receiving

nitrogen soon after planting grew faster, beginning the first year after planting, than those that received no nitrogen.
4. Live oak had similar trunk and root growth responses after transplanting, regardless of fertilizer type.
5. Addition of nitrogen had no impact on trunk growth of recently transplanted 23-cm (9-in.) caliper live oak the first 5 months after applying fertilizer, but it encouraged slightly (significant at $P < 0.03$) faster growth between 6 and 18 months after applying fertilizer.
6. Addition of potassium and/or phosphorus to the soil after planting had no impact on subsequent growth on 10- to 13-cm (4- to 5-in.) or 23-cm (9-in.) caliper live oak receiving regular nitrogen applications.
7. Trees in warmer hardiness zones (USDA hardiness zones 8 through 11) may respond to fertilizer sooner after planting than those growing in cooler climates (zones 2 through 7).

Table 1. Live oak[z] trunk diameter increase in the first 27 months after transplanting.

Fertilizer ratio[y]	Increase in trunk diameter[x] (cm)
2–1–1	4.83 a[w]
2–0–1	4.75 a
2–0–0	4.62 a
2–1–0	4.57 ab
Nonfertilized	4.17 b

[z]Average trunk diameter was 23 cm (9 in.).
[y]Fertilizer was applied at a rate of 19.5 g N/m^2/yr (4 lb N/1,000 ft^2/yr) to a 3 × 3 m (10 × 10 ft) square area around the trunk beginning 9 months after transplanting. Fertilizer ratio is nitrogen:phosphorus (P_2O_5):potassium (K_2O).
[x]Trunk diameter was measured at 30 cm (12 in.) above soil surface.
[w]Means followed by different letters are significantly different at $P < 0.03$. Each number is the mean of 32 trees.

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[1,2]*Environmental Horticulture Department*
1549 Fifield Hall
University of Florida
Gainesville, FL 32611

[3]*Disney Imagineering*
Cambridge, MA

Corresponding author: Edward F. Gilman

Résumé. Des magnolias à grandes fleurs *(Magnolia grandiflora)* plantés dans un sol sableux en contenants de 3 litres n'ont pas répondu à des applications annuelles d'azote de plus de 20 g N/m^2, et ce au cours des deux premières années après leur transplantation. L'application annuelle de 40 g N/m^2 à donné un accroissement supérieure en hauteur la troisième année qu'avec une de 20 g ainsi qu'un accroissement supérieur en hauteur et en calibre du tronc la quatrième année. Un taux d'azote supérieur à 40 g N/m^2 n'a pas résulté en une croissance supérieure. Des semis de magnolia et des chênes verts *(Quercus virginiana)* cultivés en champs de 10 à 13 cm de calibre ayant reçu des apports en azote peu de temps après leur transplantation ont répondu dès la première année en poussant plus vite que ceux n'ayant pas reçu d'azote. Les apports d'azote avaient peu d'impact sur la croissance ou la concentration azotée dans les tissus (1,4%) des chênes verts de 10-13 cm lors des trois premières années après leur transplantation ; de plus, il n'y avait pas d'effet à la source par l'azote sur l'extension des racines depuis le tronc. Tous les fertilisants renfermant de l'azote produisent une croissance. Les applications d'azote ont augmenté la croissance du tronc de chênes verts de 23 cm de calibre à compter du seizième mois après leur transplantation au moyen d'une arracheuse. L'ajout de potassium et/ou de phosphore à la fertilisation azotée n'avait aucun effet sur la croissance.

Zusammenfassung. Die Südliche Magnolie *(Magnolia grandiflora)* gepflanzt in einem 3-L Container mit sandigem Boden, zeigte in den zwei ersten Jahren nach den Pflanzung keine Reaktion auf Stickstoffgaben über 20 g N/m^2. Die Jahresgabe von 40 g N/m^2 führte zu einem größeren Höhenwachstum als die 20 g Gabe im dritten Jahr und zu mehr Höhe und Stammdurchmesser im vierten Jahr nach der Pflanzung. Größere N-Gaben als 40 g N/m^2 zeigten keine Auswirkungen. Magnoliensämlinge und im Freiland wachsende Lebenseichen *(Quercus virginiana)* mit einem Stammumfang von 10-13 cm, die direkt nach dem Verpflanzen Stickstoff erhielten, reagierten im ersten Jahr mit schnellerem Wachstum als ungedüngte Pflanzen. Die Art des Stickstoffs hatte wenig Einfluß auf das Wachstum oder die N-Konzentration im Gewebe der Eichen im ersten Jahr nach der Verpflanzung und auch die Wurzeln zeigten keinerlei Reaktion auf die Stickstoffherkunft. Alle Dünger, die Stickstoff enthielten, förderten das Wachstum. Die N-Gaben förderten das Stammwachstum von Lebenseichen mit 23 cm Stamumfang ab dem 16 Monat nach der verpflanzung durch einen Baumspaten. Kalzium und oder Phosphor in Verbindung mit Stickstoffgaben hatte keinen Einfluß auf das Wachstum.

Resumen. La magnolia *(Magnolia grandiflora)* de 3 litros (1 galón) plantada en líneas en un suelo arenoso no respondió a aplicaciones de nitrógeno arriba de 20 g N/m^2 (4.2 lbs N/1000 pies^2)/año los primeros dos años después de la plantación. La dosis de 40 g N/m^2 (8.3 lb N/1000 pies^2)/ año rindió mayor altura que la de 20 g (4.2 lb) en el tercer año y mayor altura y diámetro del tronco el cuarto año después de la plantación. Las dosis de N mayores a 40 g N/ m2 no rindieron mayor crecimiento. Los brinzales de magnolia y árboles de 10–13 cm (4–5 pulg) de calibre de encino siempreverde *(Quercus virginiana)*, crecidos en el campo, que recibieron nitrógeno inmediatamente después del trasplante, respondieron el primer año de aplicación más rápido que los que no lo recibieron. La fuente de nitrógeno tuvo poco impacto sobre el crecimiento o concentración de nitrógeno en los tejidos (1.4%) de encinos siempreverdes de 10–13 cm (4–5 pulg), en los primeros tres años después del trasplante al terreno, y no hubo efecto de la fuente de nitrógeno sobre la extensión del sistema de raíces a partir del tronco. Todos los fertilizantes con nitrógeno promovieron el crecimiento. Las aplicaciones de nitrógeno incrementaron el crecimiento del tronco en 23 cm (9 pulg) de diámetro en siempreverde, comenzando aproximadamente 16 meses después del trasplante con una trasplantadora mecánica. El potasio y/o el fósforo, cuando se aplicaron junto con el nitrógeno no tuvieron efecto sobre el crecimiento.