ROOT GROWTH RESPONSE TO FERTILIZERS[1]

by Gary W. Watson

Abstract. Granular nitrogen, potassium and phosphorous fertilizers were applied in 5 cm diameter, 60 cm deep holes near honeylocust (*Gleditsia triacanthos* var. *inermis*) and pin oak (*Quercus palustris*) trees. Each was applied separately and also together as a balanced fertilizer. After two years, root development near the holes was assessed. No evidence of phytotoxicity from the concentrated source of fertilizer salts was evident. Nitrogen, alone and in combination with the other two elements, significantly increased density of the honeylocust roots near the application holes. Pin oak root densities were only increased in the presence of nitrogen alone. Phosphorous had no effect on the roots of either species

In nutrient-rich zones of the soil, the growth of the main root is reduced while branching of lateral roots is increased resulting in greater fine root development (5). Localized applications of nitrogen fertilizer can increase root density in the immediate area (1,2,3). Excess nitrogen fertilization can reduce fine root formation (6)

Phosphorous has long been thought to promote root growth. Harris (4) reviewed the available literature and reported that there was no strong evidence to support this contention as long as phosphorous was not deficient in the soil. Similarly, Yeager (8) reported that phosphorous at levels above 85 ppm in the soil had no effect on root growth. The effect of potassium on root growth of trees has not been reported.

Arborists often apply fertilizer by drilling holes and filling them with granular fertilizers or injecting concentrated solutions. Since fertilizers contain salts, large concentrations placed in holes in the soil could be damaging to roots nearby. The purpose of this study was to investigate both the potential root damage caused by this method of application, and the potential stimulating effects of fertilizer nutrients on root development.

Methods

Study 1. This preliminary experiment was conducted in a stand of pin oaks (*Quercus palustris*) grown from seed, spaced 4 m (13 ft) apart, where previous experience indicated that the roots were dense and uniform. Soil fertility in this area was generally adequate. Four vigorous, adjacent trees (30 - 35 cm [12 - 14 in] dbh) were chosen to minimize potential variability in tree condition and soil type. It is quite probable that root systems of the trees overlapped, and that roots from more than one tree could be included in any sample, further reducing variation associated with individual trees. On June 16, 1987, two 5 cm (2 in) diameter holes, were drilled 60 cm (2 ft) deep, 1.5 m (5 ft) from the trunk of each of 4 trees. One was filled with 10-10-10 NPK fertilizer, the other was left empty as a control.

Sampling took place 7, 21, 49 days and two years (July 26, 1989) after the treatment date. A core sampler was used to remove 7.5 cm (3 in) diameter 45 cm deep soil cores, centered 10, and 17.5 cm (4, and 7 in) from each hole. To reduce the volume of each sample to be processed, segments of each core were selected for processing. These segments were 5 - 10 cm, 20 - 25 cm and 35 - 40 cm (2 - 4, 8 - 10, and 14 - 16 in) from the surface. All segments were combined to yield a representative root density for the entire core. The roots were washed free of soil and then separated from roots of other species and measured with a Delta-T Area Meter. Root measurements are expressed as densities (mm^2 root surface area per cm^3 of soil volume).

For each date, root densities in core samples near fertilizer-filled holes were compared with corresponding cores from the controls using the t-test ($P \leq 0.05$).

Study 2. A second study was initiated on May 30, 1990 to try to confirm the results of the first study more convincingly and in more detail. A

[1] Supported, in part, by the Illinois Arborist Association and Hendricksen, the Care of Trees.

second species, honeylocust (*Gleditsia triacanthos*), was added. The pin oaks were 20 - 25 cm (8 - 10 in) dbh and the honeylocusts were 22 - 33 cm (9 - 13 in) dbh. The experiment was designed as in the first study except: additional treatment holes were added around each tree; samples were taken up to 25 cm (10 in) from the hole; and each core segment was analyzed individually. The holes were 1.5 m (5 ft) apart. The treatment holes were filled with: 1) 10-10-10 NPK fertilizer, 2) nitrogen only (urea and NH_4NO_3, 45-0-0 and 32-0-0, this combination provided similar sources of nitrogen as the balanced fertilizer), 3) phosphorous only (P_2O_5, 0-46-0), 4) potassium only (K_2O, 0-0-60), 5) empty holes,and 6) vermiculite only. The single nutrient fertilizers were mixed with vermiculite in the proper proportions to yield the same ten percent analysis as in the balanced fertilizer that was used. Core sampling was performed June 16, 1992, but the individual segments were treated separately, not combined. Core segments from all treatments in the same position relative to the sampling hole were compared to the corresponding control sample using 1-way ANOVA. LSD was used to separate means ($P \leq 0.05$)

Results and Discussion

Study 1. Though there was no significant change in root density from the fertilizer treatments, roots were about twice as dense around the fertilizer-filled holes after two years (Table 1). High variability of root samples often prohibits achieving significant differences between treatments even though the differences seem quite obvious.

Study 2. A second study was undertaken to verify the root growth differences associated with the balanced fertilizer and to investigate which nutrients were responsible for the increase in root density. More detailed sampling over a broader area provided more information on how far from the treatment hole the fertilizer influences roots growth. Nitrogen was the only element that was consistently associated with significant increases in root development (Table 2). Potassium-, phosphorous- and vermiculite-filled holes showed no increase (data not presented). For honeylocust,

Table 1. Root densities associated with granular balanced fertilizer applied in holes in the soil in Study 1. There was no significant difference in root density between treated and control samples for any sampling period or distance from hole, but after two years, the roots near the holes with fertilizer were approximately twice as dense as the controls.

Days after treatment/ Core center distance from treatment hole	Root density (mm^2 surface area/cm^3 soil) Fertilizer treated	Control
7 days/10 cm	2.4	2.2
7 days/17.5 cm	1.7	1.4
21 days/10 cm	1.5	1.2
21 days/17.5 cm	1.5	1.4
49 days/10 cm	1.3	1.0
49 days/10 cm	2.1	1.6
770 days/10cm	6.7	3.5
770 days/17.5 cm	9.2	4.4

both nitrogen alone and balanced fertilizer containing nitrogen were associated with significant increases in root density. Root density was increased only within 10 cm (4 in) of the hole near the surface, but at a depth of 35 - 40 cm (14 - 16 in), root density was increased to at least 29 cm (11 in) from the hole (Table 2). This inverted cone-shaped pattern is probably related to the way nitrogen readily leaches through the soil. Only nitrogen alone significantly increased root development in pin oak, and only within 10 cm (4 in) of the fertilizer-filled holes (Table 2) Lower overall root density of the pin oak samples may explain the difference in pattern of root density increase and the lack of increase by the balanced fertilizer. With lower densities, the variation characteristic of root samples can make significance difficult to achieve.

Pin oak root densities near the control treatments changed from year to year, even though they were sampled at the same time of year, received the same treatment, and were processed in the same manner. In 1987, 1989 and 1992, average values were 1.4, 3.9 and 16.5 mm^2 surface area per cm^3 of soil volume, respectively. This variation is probably a response to changes in the soil environment. The area where the trees are growing

Table 2. When nitrogen fertilizer was applied in holes in the soil, root density of trees was increased by the nitrogen, alone or in a balanced formulation.

	Root density (mm^2 surface area/cm^3 soil)								
	Nitrogen only			Balanced fertilizer			Control		
Sample depth	10[a]	17.5	25	10	17.5	25	10	17.5	25
Honeylocust									
5 - 10 cm	123*	74	53	117*	87	68	52	50	60
20 - 25 cm	95*	58*	43	192*	59*	41	36	29	30
35 - 40 cm	113*	34*	22*	107*	36*	13	18	13	12
Pin oak									
5 - 10 cm	80*	26	26	41	36	30	28	28	29
20 - 25 cm	32*	16	16	28	19	17	13	11	9
35 - 40 cm	20*	12	8	8	10	7	10	9	9

a Distance from the treatment hole in cm
* Significantly different from control at same location ($P \leq 0.05$)

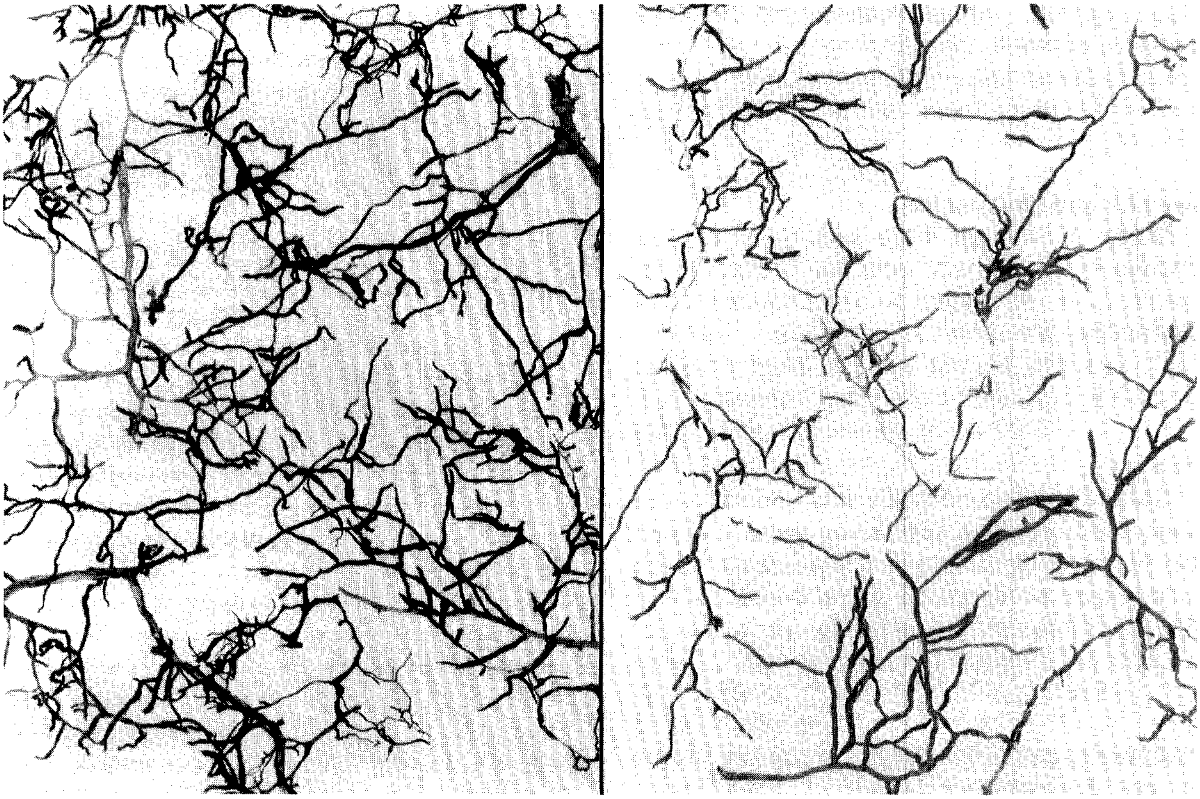

Figure 1. Honeylocust roots growing in the zone influenced by the nitrogen fertilizer treatment (left) were more dense than those of the control treatment (right).

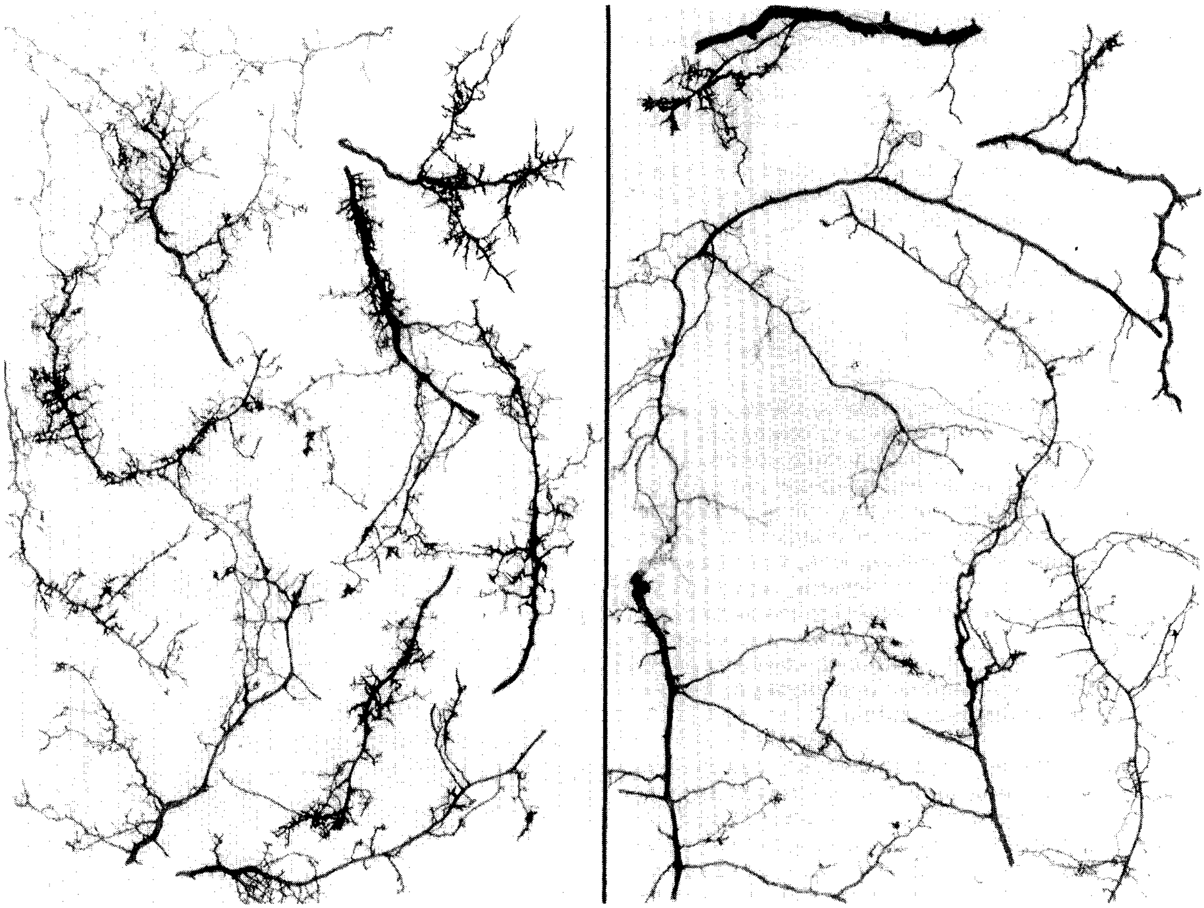

Figure 2. Pin oak roots growing in the zone influenced by the nitrogen fertilizer treatment (left) were more dense than those of the control treatment (right).

has a high water table in the spring which could potentially reduce root growth. In dry springs, like 1988 and 1989, root growth might actually be increased. The trees sampled in 1992 were in a different section of the plantation that was slightly higher in elevation and this may be reflected in the relatively high root densities.

Though the addition of nitrogen fertilizer increases root density near the point of application, this may not represent an increase in the total root mass. One report (7) suggests that root development in other parts of root system may be reduced. The lack of root growth stimulation by phosphorous in this study may help to dispel the common assumption that phosphorous fertilization will promote root growth.

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Résumé. Des fertilisations granulaires d'azote, de potassium et de phosphore étaient appliquées séparément et ensemble dans des trous de cinq et de 60 cm de profondeur près de féviers inermes (*Gleditsia triacanthos* var. *inermis*) et de chênes des marais (*Quercus pallustris*). Deux ans après, le développement racinaire près des trous était quantifié. Aucune évidence de phytotoxicité était découverte. L'azote, seul ou combiné avec les deux autres éléments, provoquait un accroissement significatif de la densité en racines près des trous de fertilisation chez le févier inerme. la densité en racines chez le chêne des marais était accrue seulement lorsque l'azote seul était employé. Le phosphore avait aucun effet sur les racines des deux espèces.

Zusammenfassung. Stickstoffgranulat, Kalium- und Phosphor-Dünger wurden separat und zusammen in Löchern mit 5 cm Durchmesser und 60 cm Tiefe neben Gleditschien (*Gleditsia triacanthos* var. *inermis*) und Sumpfeiche (*Quercus palustris*) ausgebracht. Nach zwei Jahren wurde die Wurzelentwicklung neben den Löchern untersucht. Es waren keine Anzeigen von Phytotoxizität sichtbar. Stickstoff allein und Kombination mit den zwei anderen Elementen vergrößerte signifikant die Dichte der Gleditschienwurzeln neben den Löchern. Die Dichte der Sumpfeichenwurzein wurde nur in der alleinigen Gegenwart von Stickstoff vergrößert. Phosphor hatte keinen Einfluß auf irgendeine Art.