Growth Response of Koa to Phosphorus Applications at Planting on Two Tropical Soils

J. A. Silva[1] and P. G. Scowcroft[2]; [1]University of Hawai'i, [2]U.S. Forest Service

Abstract

A field experiment with 5 rates of P (0, 150, 300, 600, and 1400 kg ha^{-1}) applied at planting was conducted with two provenances of *Acacia koa* on a Rhodic Eutrustox (Oxisol), Wahiawa soil series, and a Typic Kanhaplohumult (Ultisol), Leilehua soil series, to determine the effects of phosphorus applications on the growth and nutrient response of koa. Both provenances increased in height, basal diameter, and diameter at breast height with increasing rates of phosphorus in the first two years of growth. Growth of the low elevation provenance was better on the Oxisol than on the Ultisol. The lower water-holding capacity of the Ultisol probably contributed to the poorer growth on the Ultisol. Height of the lowland provenance increased from about 0.4 m at transplanting to 2.6 m at two years with 1400 kg P ha^{-1} compared to the unfertilized plants which increased in height from 0.4 m to 1.5 m in the same period. In contrast, the high elevation provenance increased from 0.4 m at transplanting to 1.6 m at two years with 1400 kg P ha^{-1} while the unfertilized plants increased from 0.4 m to 0.86 m in two years. Application of phosphorus at planting to phosphorus-deficient soil increased the growth rate of transplanted koa.

Introduction

There is considerable interest in reforestation with *Acacia koa* in areas where native forests have been cleared for pasture, crops, and other uses. Many of these areas have high rainfall and the soils are usually acid with high amounts of soluble iron and aluminum. These soils have low phosphorus content and can readily fix applied phosphorus making it unavailable to plants. Young koa trees transplanted in these soils with existing vegetation must compete for light, nutrients, and water. The lack of phosphorus severely limits the growth of many young plants and it is believed that the establishment of transplanted koa in these soils is hindered by the lack of adequate phosphorus. Therefore, we decided to evaluate the effects of phosphorus fertilizer applied at planting on koa seedling growth. Our objective was to determine the growth response of koa from two seed sources to phosphorus applications on two soils, an Ultisol (Leilehua series) and an Oxisol (Wahiawa series).

Materials and Methods

Location. The experiment was conducted at the Waiawa Correctional Facility located in Central O'ahu on the leeward side of the Ko'olau moutain range. It is at 250 m elevation and recieves about 1270 mm rainfall annually. Annual air temperatures average 22°C. Soils in the area belong to the Oxisol and Ultisol orders.

Treatments. The treatments consisted of five rates of phosphorus, two sources of koa seed, and two soil series. Seedlings from the Pacific Palisades seed source were planted in both the Leilehua and Wahiawa series while those from the Kukaiau seed source were planted only in the Wahiawa Series because the seed supply was limited. A comparison of seed sources was carried out in the Wahiawa series while the comparison of soils was carried out with the Pacific Palisades seed source. The treatments were installed in each soil series as a randomized complete block design with four blocks. Spacing of trees was 2m x 2m and there were 16 trees per plot. Measurements were made on the interior four data trees in each plot.

Seed sources (provenances). Seed was collected from the Pacific Palisades (PP) area on the island of O'ahu at an elevation of 275 m, with an annual rainfall of 1500 mm and an annual temperature of 22°C and from the Kukaiau (KK) area on the island of Hawai'i at an elevation of 1100 m, with an annual rainfall of 2000 mm and an annual temperature of 18°C. The seed was germinated in dibble tubes by the U.S. Forest Service on the Island of Hawai'i and the seedlings were shipped to Oahu for transplanting in the experiment.

Soils. The experiments were planted on soils of two soil orders. The Leilehua series is a Typic Kanhaplohumult (Ultisol) and the Wahiawa series is a

Table 1. Analysis of soils. (0-30 cm depth)

Characteristics	Leilehua	Wahiawa
Avail. water (pct)	8.0	16.0
pH (water)	4.8	5.0
Organic C (g kg^{-1})	26.1	29.5
Total N (g kg^{-1})	2.3	2.5
Ca (cmol kg^{-1})	0.4	1.8
Mg (cmol kg^{-1})	0.4	1.7
K (cmol kg^{-1})	0.2	1.2
Extractable Al (cmol kg^{-1})	3.10	0.45
Al Saturation (%)	74.0	5.7
P-Mod. Truog Ext. (mg kg-1)	6.7	10.0

Rhodic Eutrustox (Oxisol). The chemical characteristics of the soils are given in Table 1.

Phosphorus treatments. The five rates of phosphorus applied were 0, 150, 300, 600, and 1400 kg P ha^{-1}. The seedlings were transplanted on April 14-16, 1992 in the following manner. About half of the phosphorus, as triple superphosphate, was applied in the bottom of the planting hole, mixed with soil, then covered with a layer of soil. The seedling was positioned in the hole and about 3/4 of the hole filled with soil. The remaining phosphorus fertilizer was applied to the outer edge of the hole and the hole was filled with soil. No additional phosphorus or other fertilizer was applied to the trees.

Data collection. Plant height and stem diameter at 10 cm above the ground were made monthly for the first 12 months after transplanting and then every four months for the second year. Diameter at breast height (1.4 m) was recorded as the trees grew.

Results and discussion

Both provenances exhibited a response to phosphorus at 24 months in the Wahiawa series (Fig. 1a); however, PP was significantly taller than KK. The response to P application was essentially linear at 24 months. The PP provenance grew more slowly on the Leilehua series than on the Wahiawa series. Similar response patterns were evident in the diameter at breast height (DBH) measurements (Fig. 1b). The high Al saturation (74%), generally lower fertility, and lower water holding capacity probably contributed to the slower growth of the PP provenance on the Leilehua series.

The rate of growth of the PP provenance on the Wahiawa series over the 24-month period reflected the phosphorus treatments (Fig. 2a). The unfertilized trees grew 110 cm in this period while the trees that received 1400 kg P ha^{-1} grew 220 cm. The differences between the higher P rates became more apparent as the trees grew for 20 months or more. The growth trends were more evident in DBH and the trees that received 1400 kg P ha^{-1} at planting were growing at a very rapid rate in the last 8 months (Fig. 2b). It appears that at least 300 kg P ha^{-1} is required for reasonable growth of koa and growth is even better with higher P rates. It is interesting to reflect on the fact that the phosphorus fertilizer was applied 24 months earlier in the planting hole. At that time, the tree roots were concentrated in the soil volume of the planting hole, but as the trees grew, their roots extended far beyond the planting hole and extracted nutrients from a much larger soil volume. Apparently the applied phosphorus stimulated growth of the entire plant, including the roots, and made them more effective in extracting nutrients from the soil due to increased root length, root number, root volume, etc. The readily available supply of P in the P-deficient soil gave the trees a boost that kept them growing at an increasingly faster rate than those that received no P or smaller amounts of P at planting. Trees that received the higher amounts of P fertiilizer would have a better chance to survive in a forest than those given little or no P. This assumes competing plants would not have access to the P.

The growth rate of the KK provenance on the Wahiawa series (Fig. 2c) was much slower than that of the PP provenance. The unfertilized trees grew 40 cm in the 24-month period while the trees that received 1400 kg P ha^{-1} grew 120 cm in the same period. This is in marked contrast to the growth of the PP provenance mentioned above. The response to P application was minimal in the first year with the 150 and 300 kg P rates producing similar growth and the 600 and 1400 kg P ha^{-1} treatments having similar growth, but it was higher than that with the 150 and 300 P treatments. After the first year, the effects of the P rates became more evident, although they were not very large. The reduced growth rate of the KK provenance is strikingly evident in the DBH measurements that never exceed 1 cm (Fig. 2d). The decrease in DBH after 12 months is due to the death of the main stem and the growth of secondary stems that were smaller. In many plants the apical buds

Figure 1. The effect of five rates of phosphorus fertilization applied at time of planting on height and stem diameter at breast height of two provenances of 24-month-old *Acacia koa* planted in an Oxisol (Wahiawa soil series) and an Ultisol (Leilehua soil series).

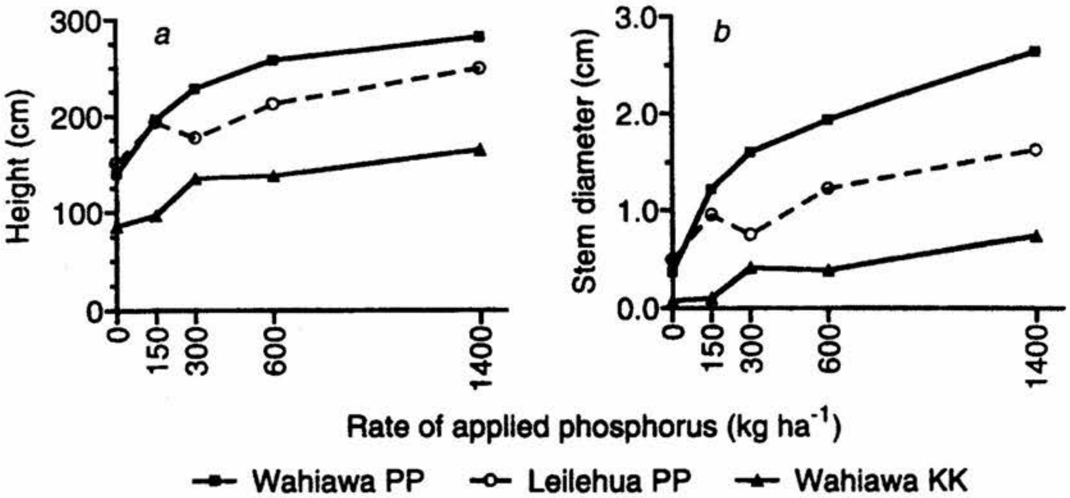
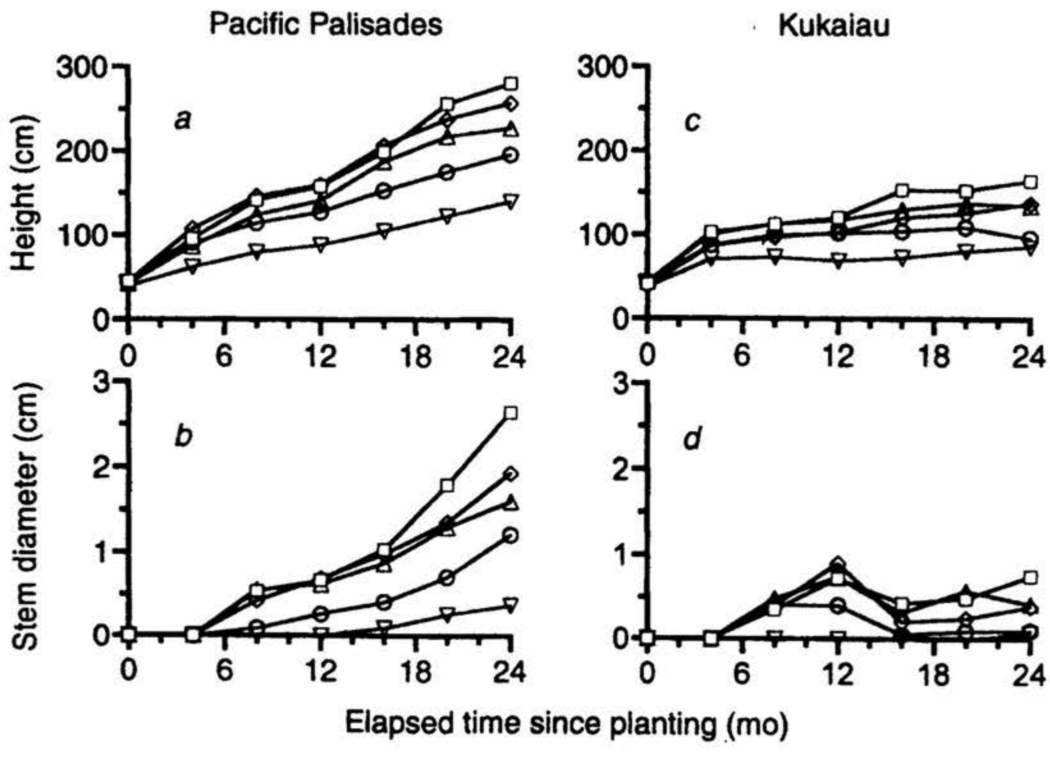


Figure 2. Mean height and stem diameter at breast height growth of *Acacia koa* trees during the 24-month period following planting in an Oxisol (Wahiawa soil series) as a function of seed source and the rate of phosphorus applied at time of planting.



remained dormant or the tip of the stem died. Obviously the KK provenance was not adapted to the environment at the site and did not grow well. This emphasizes the importance of selecting a koa provenance from a site with similar environmental conditions as the site in which it is going to be planted.

Conclusions

The following conclusions may be drawn from this study.

1. Both koa provenances benefitted from application of phosphorus at planting and the effects were still evident at 24 months after planting.

2. For the Pacific Palisades provenance, maximum growth at 24 months was obtained with 1400 kg P ha^{-1} on both soil series. For the Kukaiau provenance, maximum growth was also achieved with 1400 kg P ha^{-1}, but the increase over 300 and 600 kg P ha^{-1} was small.

3. The Pacific Palisades provenance was better adapted to the environment of the Wahiawa series than was the Kukaiau provenance.

4. Growth of the Pacific Palisades provenance was better on the Wahiawa series than on the Leilehua series.

Acknowledgements

The authors acknowledge the financial support of the Governor's Agricultural Coordinating Committee Contract No. 91-04. The administrators of the Waiawa Correctional Facility, who made the land available for the experiments, are also acknowledged. The contribution by the U.S. Forest Service of supplies and the assistance of David Fujii, Janis Hariguchi, Don Goo, and Alan Urakami is appreciated. The assistance of Stanley Oshita and Servillano Lamer of the Department of Agronomy and Soil Science of the University of Hawai'i is also appreciated.

Questions

Q: You mentioned that you were using treble super phosphate as your phosphate source. Isn't that highly soluble? At the end of the 24 months how much of the original application will still be there for use by the plant?

A: Probably not a great deal, but phosphorus, although it's very soluble when you first add it, does get tied up as iron phosphate in soils with low pH. Therefore, although it's not immediately available, it can be released over time, gradually. So there would still be some slow release of some of the phosphorus that's there. I remind you it's in a very small area or volume of the soil. When we applied the phosphorus, we put some of it in the bottom of the hole before planting, mixed it up with a layer of soil, then put the seedling in. As we covered it up, we had about 2/3 of the hole filled, we applied the rest of the phosphorus in a ring on the outside of the 8-inch holes, and that's all they had. It was very close. When the roots first came out they had a very good supply of phosphorus, but then as they grew out they got into the soil itself. Koa does have mycorrhizal associations and therefore, with the mycorrhizae and that large root volume that they eventually had with the high phosphorus, they were able to pick up phosphorus in the soil.

Q: Did you test and see if there were any mycorrhizal associations with all of the different provenances at the different sites?

A: We didn't actually measure that, but we should have. Generally, forest koa does have. There is koa in the vicinity, so my guess is that it is mycorrhizal.