BLACK WALNUT: WHAT CAN NEW ZEALAND LEARN FROM THE UNITED STATES?

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ABSTRACT

Black walnut (Juglans nigra) is being considered for planting in New Zealand as a high-value timber tree. Although single specimen trees have grown well on good sites in New Zealand, very little local information is available about this species.

In the United States, black walnut occurs throughout the eastern and central regions. Natural stands are being creamed of higher grade trees, and prices for walnut logs are increasing. Despite intensive research on establishment and silviculture, many black walnut plantations fail because they are not planted on well-drained, deep, fertile soils.

Because of the absence of squirrels in New Zealand, it may be possible to establish plantations from direct sowing. Intensive plantation culture, including weed control with cultivation or herbicides, pruning to improve form and produce clear timber, interplanting with nitrogen-fixing species, and thinning before canopy closure, appear necessary to obtain rapid growth.

Seed from various United States provenances is being imported to find the best seed source for New Zealand conditions.

INTRODUCTION

Black walnut (Juglans nigra) is indigenous to eastern North America, from Ontario south to Texas in the west and Georgia in the east. The timber has good woodworking qualities, an attractive brown colour, and is stable in use. It currently commands a higher price than other hardwoods, and the demand, especially from European buyers, for good quality logs is greater than the supply. It is site demanding, growing well only on deep, well-drained, fertile soils. In the United States, numerous papers have been published on the requirements and silviculture of this species. Useful summaries have been given by the United States Forest Service (USDA, 1973), and by Schlesinger and Funk (1977).

Interest in the species in New Zealand is widespread among tree crop and farm forestry groups. Though some tree crop

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enthusiasts are farmers, many are owners of small blocks of rural land and are looking at black walnut as a high value species, capable of producing nuts in addition to timber. They see it as an attractive alternative to *Pinus radiata*. Similarly with forest farming (tree crops grown over pasture) there is interest in using more demanding but valuable species such as black walnut on fertile sites.

An evaluation of black walnut based on the few hundred mature trees presently growing in New Zealand has not yet been completed, but a number of problems are already evident. Unknown parentage is one. In a species of such diverse natural geographic distribution (Fig. 1) the origin of the parent tree will have a considerable bearing on the vigour of progeny in New Zealand. The species' potential is further obscured by most New Zealand specimens being open-grown on good sites — i.e., near Gisborne, in the Waikato, and around Tauranga. Performance in plantations and on poorer sites is

![Fig. 1: The range of black walnut (from Fowells, 1965)](image-url)
not known. Unknown age of these trees is also a hindrance to interpreting growth rates here. Increment boring of specimen trees cannot be recommended as it is reported to introduce stem rot (Clark, 1966).

It would be difficult to evaluate black walnut in New Zealand without first studying the species in North America. During August 1977, the writer travelled through Nebraska, Missouri, Illinois, Indiana, Kentucky, Tennessee, and North Carolina. Black walnut was also observed in Washington, Oregon, and California. The objectives were to examine natural stands of black walnut, the scope and success of the planting programme, research relevant to the species, and progress on combining black walnut with agricultural systems as is being considered in New Zealand. The study tour also allowed the importation of seed from various regions for provenance testing and comparison with New Zealand seed sources.

NATURAL STANDS

Black walnut usually occurs as single trees, or groups of trees, on river terraces or lower valley slopes. Squirrels distribute and bury walnut seed, and walnut regeneration is commonly seen at the edge of mixed hardwood forest, and along fence lines. Dense “natural” stands growing on abandoned pig fields are quite common in Missouri. In eastern Nebraska, young walnut can be seen emerging from beneath elms killed by Dutch elm disease.

Natural stands respond well to thinning, provided they have not stagnated. Funds are available from a Federal incentive programme, which subsidises up to 75% of the cost of any stand improvement such as thinning. However, the proportion of natural stands receiving silvicultural treatment seems to be very small.

The term “high-grading” is frequently used to describe the system used in selecting the best trees in uneven-aged forest for harvest. “High-grading” results in a disproportionate volume of the stand concentrated in young and poorly formed trees, and also in removal of the best seed trees. Merchantable trees are generally over 50 years of age.

Walnut is susceptible to hormone weedkillers and damage from aerially applied herbicide is common during spring and early summer, particularly in Nebraska, Kansas, Missouri, and Iowa. Most of the trees are scattered across agricultural land, so are extremely vulnerable. One direct spray or three drift sprays of 2,4-D can kill or severely retard even mature trees.
UTILISATION OF NATURAL WALNUT

Timber

High prices are sometimes received by landowners for individual trees of black walnut, and widespread publicity has followed some sales, even to the extent of being reported in New Zealand. I was told that log buyers will occasionally pay inflated prices to obtain publicity, thus encouraging other landowners to come forward. The buyer then has various reasons why particular trees are not valuable, but landowners are by that stage "conditioned" to sell and lower prices are accepted.

Logs free of defect and suitable for sliced veneer fetch prices of $200 to $600/m³ true volume, depending on diameter, length, proportion of sapwood, and location. Sawlog prices range from $20 to $100/m³ true volume. (See Fig. 2.) Green rough-sawn timber sells at $320/m³ (sawn) for the best grades. Large sizes and long lengths are difficult to obtain, and degrade during drying commonly leads to 10 to 40% wastage. Mahogany, which is similarly priced to walnut, and pecan (Carya illinoensis) at $120/m³ were considered by two North Carolina furniture manufacturers to be better value than walnut. The Drexel Furniture Company of Mortanton, North Carolina, with 1000 employees, uses 2500 m³ of timber per week, the only walnut being a small quantity of veneer. They suggested that, given the choice and the price differential, consumers preferred pecan to walnut.

![Fig. 2: Stumpage prices, black walnut veneer and sawlogs, Indiana, U.S.A. (Source: Walnut Council Newsletter, 5 (1), March 1978.)](image-url)
Most walnut is kiln dried. The schedule given by the United States Department of Agriculture (Rasmussen, 1961) is considered rather drastic, and in practice the time schedules given in the manual are usually doubled: 25 mm thick boards are dried on a 28- to 30-day schedule, and 50 mm thick timber on a 100- to 180-day schedule. Prefreezing has been used experimentally to reduce drying time, and applied commercially to gunstocks. Presteaming followed by air drying to 30 to 35% moisture content permits a faster kiln schedule. Air drying may be used, but the use of an open-sided shed is recommended to reduce excessive end checking.

Nuts

Almost all the nuts which are harvested come from “natural” trees, and in every 5 years black walnut usually produces one heavy crop, two moderate ones, and two light.

Hammons Products Co. of Stockton, Missouri, has two nut-extraction plants in Missouri and Arkansas, accounting for 40% of the United States production. The company supports 300 buying stations in 18 states and pays $3 to $5 per 50-kg bag of de-husked nuts (depending on the season). In 1976 (an average year), 9 million kg of cleaned, in-shell nuts were purchased. The buying stations are located at country stores or farm product firms, and operate simple, trailer-mounted, de-husking machines. The de-husked nuts are air dried at the two factories to 15% moisture content, kiln dried to 7% moisture content, and then cracked. Hammons have a staff of 130, and an annual revenue of about $6 million, about one-quarter of which comes from sales of shells. Crushed shells are used in the automotive industry for polishing gears and cylinders, and the fines are used as filler in glue and paint. Nut meat is used mainly for ice cream flavouring, and also in confectionery and for home cooking. Livestock feed is a minor product manufactured from finely mixed shell and nut meat with maize added.

There is little evidence of current research on finding improved strains of black walnut for nut production, presumably because of the species’ relative inefficiency (heavy shell, low nut-meat content, and light yields) compared with the main producers — pecan (in the south) and English walnut (Juglans regia) in California. A total of 22 300 tonnes of “in-shell” black walnut is harvested annually in the United States, compared with the English walnut harvest of 210 000 tonnes and a pecan harvest of about 220 000 tonnes. Whereas black walnut yields about 8% saleable nut meat, English walnut and pecan yield 45 to 50%. In terms of nut meat, the United
States commercial walnut harvest is 98% English walnut and only 2% black walnut.

PLANTED STANDS

In view of the declining quality and volume of naturally grown black walnut timber, it is not surprising that extensive research has been done on growing it in plantations.

Provenance Testing

Provenance testing has been carried out by the U.S. Forest Service Forestry Science Laboratory at Carbondale, Illinois, and the Tennessee Valley Authority at Norris, Tennessee. Comparisons of growth of progeny from selected parent trees have also been made by the North Carolina Forest Service, Missouri Department of Conservation, and more recently by Purdue University in Indiana.

In general, the early provenance trials in southern Illinois have shown that provenances from southern sources (i.e., Texas) grow better in this area than those from northern sources (i.e., Iowa), but flush earlier and are therefore prone to damage from late frosts. However, bud burst in southern provenances was only about 2 weeks ahead of northern ones, a difference which, if maintained in New Zealand, would make little difference in the face of late spring frosts common here. Southern provenances have also grown better in a trial at Yoncalla in southern Oregon — a region with a climate more similar to New Zealand. The progeny testing is still at an early stage, and there are no improved strains available for the various provenances.

Nursery Practice

About 2 million black walnut seedlings are grown in United States nurseries each year. For spring sowing the seed is collected in the autumn, de-husked, immersed in water to detect hollow shells, dried to 15% moisture content, and then stored at 3°C for a minimum of 60 to 90 days. With the more common autumn sowing seen at the Vallonia nursery in Indiana (200 000 1/0 seedlings), NPK (1:4:4) fertiliser is applied prior to sowing, with the nitrogen applied as 168 kg/ha of ammonium nitrate. The seed is sown into fumigated soil immediately after de-husking, with five rows per 1.1 m wide bed. It is sown 4 to 5 cm deep and then covered with a mulch, such as wood fibre. A 65% germination rate reduces seeds sown at 80/m² to a seedling density of 52/m². In midsummer, when the seedlings are 25 to 30 cm in height, they are sprayed with malathion for aphid control, with benlate for anthrac-
nose (leaf blight), and copper hydroxide for bacterial spots caused by an as yet unidentified disease.

Seedlings are lifted in the spring, since this has been found to result in less incidence of *Phytophthora* (root rot disease) than autumn lifting. During lifting, the taproot, which often measures 0.9 m, is cut at 0.25 m with an angle wrencher. Generally, no undercutting or wrenching is done except at time of lifting.

The soils at the Vallonia nursery and at others at Norris, Tennessee, and Morganton, North Carolina, are very sandy. The Vallonia soil has a pH of 6.5 and contains only 1 1/2% organic matter. Irrigation is frequently used throughout the summer; however, soil moisture levels are kept relatively low to encourage fibrous rooting. At Morganton, the seed is also sown in the autumn but with the husks on. Nitrogen is used at the rate of 168 kg N/ha; heavy dressings of nitrogen have been found to reduce anthracnose — the most prevalent disease. The price of 1-year-old walnut seedlings ranges from $20 to $200 per thousand at various State nurseries. The latter price is probably closest to the cost of production, with lesser prices reflecting State and Federal subsidies.

**Site Requirements**

Black walnut requires a good site. Probably between one-half and two-thirds of the plantations planted to date have failed or are unthrifty because of poor siting. Vigorous, healthy plantations are usually growing on well-drained lower river terraces, on fertile soil up to 1 m in depth. Unthrifty plantations are often on broad ridges, shallow or poorly drained soils, or south-west slopes which tend to dry out in summer. Plantations on poor sites often showed premature leaf fall resulting from heavy infection with anthracnose.

**Site Preparation and Tree Establishment**

Seedlings are usually hand-planted as 1/0 stock into cultivated soil, and herbicides such as paraquat combined with atrazine or simazine are sprayed prior to planting to reduce weed competition.

A number of plantations have been established from direct seeding, a practice that would be more widely used if squirrels were less of a problem. In Missouri young trees aged 2 years from direct seeding were considered equal to trees planted 3 years previously as 1/0 seedlings.

At Fort Campbell, Kentucky, nuts were collected in the autumn and stored in open plastic bags in a shed over the winter. In the spring they were planted (some with the husk
remains still on) 5 cm deep in a disced paddock. About 80% germinated and grew.

**Intercropping**

The largest intercropping venture seen was at Stockton, Missouri, where 120 ha were planted in black walnut at 12 × 3 m spacing. A crop of wheat was followed by soya beans between the rows. The oldest trees were only 3 years old — too young for assessment of their long-term performance and of whether apical dominance would be sufficient to produce veneer or sawlogs. However, it was obvious the trees benefited from the frequent irrigation and fertiliser application given the wheat and soya beans. The encroachment of weeds into the crops from a strip along the tree rows was a problem, as control of the established weeds with herbicides was complicated by the presence of the black walnut.

In Nebraska, crops of wheat have been taken from between rows of 2-year-old walnut spaced at 9.1 × 1.8 m on a 3 ha plantation. Simazine was used to prevent weeds becoming established along the tree row. At Fort Campbell, Kentucky, maize was being successfully grown between 7-year-old black walnut at 6 × 6 m spacing.

Apparently no research work has been done on the toxic effect of walnut on other vegetation since Brooks (1951) showed that walnut is toxic to lucerne and some crops such as tomatoes, but not to grasses or clovers.

A research trial at Stockton, southern Missouri, managed by the University of Missouri and aimed at investigating the relationships between various hay crops, pasture, and widely spaced walnut, was not sufficiently advanced for conclusions to be drawn. At the Forestry Sciences Laboratory, Carbondale, southern Illinois, I was told that the minimum initial stocking to ensure adequate selection of vigorous trees showing good apical dominance was 1000 stems/ha. Intercropping would be possible only if rectangular spacing such as 6 × 1.7 m was adopted. On exposed sites, loss of apical dominance is commonplace, and 1000 stems/ha does appear necessary. However, on sheltered sites 500 stems/ha may suffice.

**Interplanting with Nitrogen-fixing Species**

Walnut plots interplanted with nitrogen-fixing shrubs and trees such as autumn olive (*Elaeagnus umbellata*), European alder (*Alnus glutinosa*), and prickly acacia (*Robinia pseudoacacia*) were compared over a 9-year period with control plots (no interplanting) by the Forestry Sciences Laboratory at Carbondale in Illinois, Missouri, and Indiana. Autumn olive
was preferred to European alder or prickly acacia as it did not overtop the walnut and become too competitive. Walnut growing amongst the autumn olive grew an average of 82% more in height and 96% more in diameter, had better form, and was also less affected by disease. It was estimated that shelter provided by the interplanted species contributed about one-half of the benefit.

Pasture legumes were tried, but no benefit could be obtained. However, they are difficult to establish and maintain in the central United States, and a more thorough evaluation in New Zealand would seem justified.

**Coppicing, Thinning, and Pruning**

Coppicing has frequently been used in research trials if young trees show dieback or serious malformation such as basket whorls or multiple leaders. Where seedlings were 1 m or less in height, and cut in winter, the coppice regrowth was found to equal the height of equivalent uncoppiced seedlings within 1 year. If the young trees were 2.5 m in height, the coppice grew to between 80 and 90% of uncoppiced seedlings. Since bent or forked trees tend to straighten out with time, no advantage was found with coppicing small (1 m) seedlings. However, coppicing trees 2.5 m in height did result in trees of better form.

As with most hardwood species in the United States, very little information is available on the effects of thinning planted stands, especially on the response of the various elements in the stand. In Nebraska, stands planted at 1750 stems/ha in 1969 were being thinned to waste to 500 stems/ha at height 8 m, d.b.h. 10 cm. It was hoped that a further thinning at 25 cm d.b.h. would be commercial. In southern Illinois, staff of the Forestry Sciences Laboratory had considerable difficulty in locating a uniform stand of 5 ha or more in which to locate trials to measure thinning response. At Martinsville, Indiana, a total of 32 ha has been planted in black walnut at 950 stems/ha, much of it interplanted with a similar number of stems of European alder. No thinning has been done yet, and with the walnut now up to 9 m in height and 10 to 12 cm in diameter, competition with the alder appears severe. Ten-year-old trees were growing at 8 mm diameter per year, compared with an annual increment of 12 mm 2 years ago.

Pruning is more commonly practised than thinning. In Nebraska the State Forest Service found that a 5 cm diameter branch would occlude cleanly, and rot or occlusion defect was no problem. Lopping branches about 1 m out from the stem to prevent excessive branch diameter growth, pruning alternate or troublesome branches, and form-pruning double
leaders are three practices which are common in research trials. The effects of various levels of green crown removal are being studied by the Forestry Sciences Laboratory at Carbondale. Pruning was found to depress diameter growth but stimulate height growth. Early heavy pruning (80% crown removal) produces whippy trees which are easily damaged by gales. A common prescription is to prune between 40 and 50% of the crown after the tree has reached 3 to 4 m in height, aiming for a knotty core not larger than 15 cm and a clear bole of between 2.7 and 5.2 m. Pruning tools and methods appear antiquated by New Zealand standards, which is not surprising as species other than walnut are not usually pruned.

Growth and Yield of Plantations

Some indication of height growth of black walnut plantations is given by Brinkman (1966) who published a comprehensive site index table prepared from approximately 200 plantations in the mid-western states, which were unmanaged but reasonably well stocked (Table 1). The same stands were used to derive yield tables for individual trees (Table 2). Tree crown areas were correlated with tree d.b.h. for black walnut by Krajicek (1966) and these have been arranged in tabular form by Schlesinger and Funk (1977). They have shown that between 70 and 90 trees of 50 cm d.b.h. can be grown per hectare, but if crop trees of 60 cm d.b.h. are re-

<table>
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<tr>
<th>Site Index (m)</th>
<th>12.2</th>
<th>15.2</th>
<th>18.3</th>
<th>24.4</th>
<th>27.4</th>
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<td>10</td>
<td>4.3</td>
<td>5.5</td>
<td>6.7</td>
<td>7.9</td>
<td>8.8</td>
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<td>6.1</td>
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<td>11.0</td>
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<td>20.7</td>
<td>24.4</td>
<td>27.4</td>
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</tbody>
</table>

*Site index shown is the midpoint of a 3.05 m class (from Brinkman, 1966).*
TABLE 2: ESTIMATED INDIVIDUAL TREE YIELDS (m³) OF PLANTATION-GROWN BLACK WALNUT IN THE CENTRAL UNITED STATES

<table>
<thead>
<tr>
<th>d.b.h.o.b. (cm)</th>
<th>15.2</th>
<th>18.3</th>
<th>Total Height (m)</th>
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<tr>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>30.5</td>
<td>0.49</td>
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</tr>
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<td>0.86</td>
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</tr>
<tr>
<td>45.7</td>
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<td>1.28</td>
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</tr>
<tr>
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<td>1.59</td>
<td>1.87</td>
</tr>
<tr>
<td>55.9</td>
<td>1.61</td>
<td>1.94</td>
<td>2.27</td>
</tr>
</tbody>
</table>

Volumes are to a 10 cm (o.b.) top, and allow for a stump 0.3 m in height. (From Kellogg, 1940)

required then the stocking must be reduced to between 50 and 70 trees per hectare.

Some caution in applying growth data is advised by Schlesinger and Funk (1977) who state “Intensive management of black walnut plantations is recent enough that no growth and yield information is available for managed plantations, and the limited information available from unmanaged plantations is considered too conservative for managed plantations”.

Veneer production from at least one pruned 2.4 m butt log would appear to be the goal of most plantations, with either a second veneer log or a 4 to 6 m sawlog taken from above the butt log, depending on bole length and branching habit of the trees in the stand.

Rotation lengths of 35 to 40 years have been given by Boyette (1973) for good sites in South Carolina, but over most of its range rotations of 45 to 50 years would seem necessary to achieve trees of 40 to 50 cm d.b.h.

DISEASES AND PESTS

Walnut is affected by a large number of diseases and insects. Walnut anthracnose (*Gnomonia leptostyla*), which fortunately is not present in New Zealand, appears to be the most damaging agent. It causes premature leaf fall and results in light, open crowns in mid-summer. Anthracnose requires only 12 hours of dew to develop, and can also affect English walnut and other hardwoods such as *Platanus* and *Liquidambar*. It is commonly accepted that the incidence of anthracnose is reduced by heavy applications of nitrogenous fertiliser, and this effect is also indicated by its virtual absence from plots interplanted with nitrogen-fixing species. It is possible that anthracnose could be imported into New Zealand within defective shells.
Two new diseases have recently been discovered. One, confined to southern Illinois and Ohio, is a leaf spot disease causing a bulls-eye type scorching, leading to premature defoliation. The Forestry Sciences Laboratory at Carbondale found that application of fertiliser did not reduce the incidence of this disease, but fertilised trees refoliated the same year. A Fusarium fungus found in North Carolina is suspected of having some interaction with ambrosia beetles (Xylosandrus spp.). An intensive study of this disease is currently being conducted by staff from the Carbondale laboratory.

Two root-rot fungi which are widespread, particularly in nurseries and usually associated with poor drainage, are Phytophthora and Cylindrocladium spp. Both are usually fatal. No association between Phytophthora and root damage caused by cattle grazing open woodlands of walnut has been reported. However, Schlesinger and Funk (1977) warn that “heavy grazing with its associated soil compaction and physical damage to the root systems can reduce sawtimber yields by as much as 20 percent”.

The most harmful insects, in order of importance, are bud borers (Acrobasis spp.), ambrosia beetles (because of their link with the Fusarium fungus described above), walnut caterpillar (Datana integerrima), and webworm (Hyphontria spp.). Outbreaks of the latter two are visually dramatic, but apparently the effect is not great. With the exception of spring frost damage, bud- and shoot-feeding insects are the major causes of stem deformity and height suppression. A Missouri study (Kearby, 1975) showed that 25% or more of trees were affected by insects over a 5-year period. Neither cultural nor insecticide control techniques have been developed.

BLACK WALNUT ON THE WEST COAST

Black walnut is grown as an ornamental tree from Seattle south, and is quite common in southern Oregon and the Sacramento Valley. These trees are well outside the natural range of the species and, in that the climate is more similar to New Zealand, may give some indication of the likely performance of the species here. The trees are remarkably vigorous and healthy compared with trees in the east. The dry summer of southern Oregon and California would presumably inhibit anthracnose and, as the trees are usually growing on deep fertile soils on valley bottoms, nutrients and moisture would not appear to be limiting.

Juglans hindsii (Californian black walnut) has a very limited natural range along streams and rivers inland from San Francisco, but has been planted as an ornamental throughout California. The timber is reported to be similar to Juglans
The tree is slightly smaller than eastern black walnut, and is widely used as root stock for English walnut orchards, being more drought- and disease-resistant than either *J. regia* or *J. nigra*. *Juglans hindsii* may grow well in New Zealand, particularly in drier areas such as Hawke's Bay and Canterbury.

**EXTENSION AND LIAISON**

Landowners obtain advice on growing black walnut from various sources — University and State extension staff, State and private forestry (the extension arm of the U.S. Forest Service), research centres such as at Carbondale, or from other landowners.

The Walnut Council, made up of landowners and research and extension staff, has as its object the promotion of the planting, management, and utilisation of walnut. However, the eighth annual meeting at Nashville Indiana, was rather disappointing in the lack of technical discussion and the reluctance of members to come to grips with current problems of walnut management and utilisation. The most important questions needing investigation are: Why do most woodlots fail? On what scale and under what conditions can plantations be established and managed? How can management practices be economically applied to increase the quality of logs from natural stands? What will be the rotation length, yield, and quality of plantations? Unless these problems are faced realistically, there is every likelihood of walnut being in the same position as New Zealand kauri, possibly within 10 years.

**CONCLUSIONS FOR GROWING BLACK WALNUT IN NEW ZEALAND**

The vigour of black walnut in Washington, Oregon, and California, and even the few trees we have here, indicate that this species may grow well in New Zealand. If it is to be successfully grown as a plantation species here, it would need to be kept disease-free, and generally grow more vigorously than it does within its natural range. A thorough evaluation of the existing trees in New Zealand is needed so that as much as possible can be learnt about growth rates, timber quality, site sensitivity, and tolerance to spring frosts and wind. Provenance testing is required in New Zealand, and the Forest Research Institute has been fortunate in obtaining the co-operation of the U.S. Forest Service and the Tennessee Valley Authority in this respect. Until the various provenances are systematically evaluated there can be little justification for the importing of seed.
New Zealand-grown black walnut could be used as furniture-grade material, for either the domestic or export markets. With the emphasis on producing quality rather than quantity, large-scale planting would not be necessary to ensure market viability.

Because of the current enthusiasm being shown for black walnut, it is unlikely that the present lack of local information about the species will inhibit its widespread planting. It is almost certain that many plantations of black walnut will be badly sited and managed. The following points are made in the hope that some disappointment can be avoided.

Fig. 3: A 100-year-old black walnut at Omokoroa, near Tauranga. The tree contains 3.8 m³ in the butt log, and measures 92 cm d.b.h.
(1) Collect nuts from local trees. These trees have already proved they can grow here, and their offspring have every chance of performing as well as trees grown from expensive seed imported from the United States.

(2) Consider direct sowing of nuts rather than planting seedlings. In cooler areas sow the husked nuts in the autumn straight into soil which has been cultivated and/or treated with herbicides such as paraquat and simazine at normal rates for long-term pasture control. In mild areas store the husked nuts through the winter in a cool store, and sow in the spring.

(3) Select sheltered, well-drained areas with a fertile deep soil. Start off with 1 ha rather than 10.

(4) Interplant or encourage nitrogen-fixing species, to provide both shelter and nitrogen. Suitable species will have to be found by trial and error. Lupin or tree lucerne in combination with white clover may be one solution.

(5) Early plantations should be at $3 \times 3$ m, or equivalent rectangular spacing, to ensure selection of straight trees showing good apical dominance.

(6) Do not prune excessively — 40% crown removal is probably adequate, starting at tree height 3 to 4 m. Aim for a 5 to 6 m pruned butt log by height 12 m.

(7) Thin to between 75 and 100 trees per hectare by tree height 12 to 15 m, aiming for a final-crop tree of about 50 cm diameter. If trees this size can be grown in 30 to 40 years, black walnut could have a minor but useful role in New Zealand's afforestation programme.

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