ECONOMIC EFFICIENCY OF TWO PRUNING HEIGHTS IN BLACK WALNUT

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Abstract. --Discounted net worth and internal rate of return were used as measures of economic efficiency of two black walnut plantation management alternatives: 1) emphasizes nut production by pruning to 9 feet of clear bole and 2) emphasizes timber production by pruning to 17 feet of clear bole, grown under intensive forest culture. Volume growth and nut yield were simulated for up to 80 years of age. Market prices for timber and nuts were averaged over the four-year period from 1974 to 1978. Given a 6.75 percent annual compound interest rate, alternative 1 was superior to alternative 2 as judged by discounted present net worth. However, if the annual compound interest rate is less than 5 percent, pruning to 17 feet of clear bole is more profitable. When the internal rate of return is used as a criterion, alternative one should be chosen for rotation ages longer than 40 years.

Additional Keywords: Black Walnut, Pruning, Simulation

INTRODUCTION

Black walnut is one of the most valuable central hardwood species. Desirable timber characterestics include a rich brown heartwood, good shock resistance, stability in drying, adaptability to milling and tool working because of its straight grain and hardness. These properties make it desirable for furniture, gunstock and interior paneling. Furthermore, the demand for black walnut products is not limited to timber. The larger strongly favored nuts and extremely hard shells make the seeds a second source of revenue. The nuts are used in household and commercially prepared foods, and the shells can be ground and used for activated carbon in gas masks, drilling mud in oil well and as an abrasive material for polishing metals (Wylie 1966).

The objective for this study is to compare the economic efficiency of two black walnut plantation management alternatives: 1) emphasizes nut production by pruning to 9 feet of clear bole and 2) emphasizes timber production by pruning to 17 feet of clear bole. Both represent stands grown under intensive silviculture. These two pruning alternatives were outlined by Schlesinger and Funk (1976).

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Results from this study are useful to forestland owners in selecting the best pruning height for black walnut plantations. Tree improvement workers can also use this study to concentrate their effort in selecting for timber or selecting for nut yield.

SIMULATION

Because no mature black walnut plantations were previously managed according to those two alternatives under controlled conditions, we can only use simulation results for comparison. However, efforts have been made to use the most up to date input data and reasonable assumptions so that the results from simulation would closely resemble the true world situation. In general the simulation procedure involves three parts: 1) growth simulation, 2) revenue simulation, and 3) cost simulation. Detailed description of these three parts are as follows:

Growth simulation

Assuming a site index for black walnut at age 50 equal 75, we can predict height growth according to the following model (Ferrell and Lundgren 1976).

Total height=1.2756 (site index) (1.0 - (e** - 0.02836 (Age)) *0.87915

Given diameter growth estimates from Naughton (1970), we further compute crown diameter in feet using the Krajicek's (1966) model.

Crown width=1.993 (dbh) + 4.873

Assuming the crown to be circular, crown area is obtained by .7854 (crown width)**2. Crown area then is used to calculate the crown competition factor (Schlesinger 1975) for the plantation.

As soon as the crown competition factor reaches 100, or total crown area equals to the ground area, the plantation will be thinned back to 70 percent of ground area. Assuming that the initial stocking is 106 trees per acre, there are 6 thinnings done at age 23, 28, 36, 44, 55 and 66. The simulated growth and stocking of a black walnut plantation from age 10 through age 80, at an interval of 5 years are presented in Table 1.

All trees were assumed to be pruned to a clear bole height of 9 feet in two stages at age 5 and age 10. For the hypothetical plantation which emphasizes timber production, the third pruning to 17 feet was done at age 17. This is consistent with the recommendation that no more than 25 percent of the live crown be removed in any year, that no less than 50 percent of the live crown be retained at any time, and that live pruning be completed before diameter at breast height(dbh) reaches 10 inches (Schlesinger and Funk 1976).

We also assumed that only one log per tree is of economic importance.

Table 1.--Simulated growth and stocking of black walnut by age

Age (years)	Average total height (feet)	Average d.b.h. (inches)	Average crown radius (feet)	Number of trees per acre	CCF (percent)
10	28	4.9	7.3	106	41
15	38	6.8	9.2	106	65
20	46	8.3	10.7	106	88
25	53	10.0	12.4	80	79
30	59	11.9	14.3	53	80
35	64	13.5	15.9	53	98
40	68	15.2	17.6	40	89
45	72	16.8	19.2	28	72
50	75	18.4	20.8	28	87
55	78	20.0	22.4	21	76
60	80	21.6	24.0	21	87
65	82	23.3	25.7	21	100
70	84	24.9	27.3	15	80
75	86	26.5	28.8	15	90
80	87	28.1	30.4	15	100

For alternative one which emphasizes nut production by pruning to 9 feet of clear bole, we assumed that one 8-ft. log is available. Similarly, for alternative two which emphasizes timber production by pruning to 17 feet of clear bole, one 16-ft. log will be yielded. The upper diameter of the log is computed by dbh and by using the Girard Form class 78 relationship. This diameter of the small end of the log and the log length described above were used to compute log volume in board feet according to the Doyle log rule. Thinning yields from the two alternatives are presented in Table 2.

Nut yields for trees in alternative 1 were first derived from a regression equation (Zarger,Farmer, and Taft 1970):

Yield=-50.7+4.76(crown radius)+0.656(dbh)+0.032(height)-0.387(age)

Because black walnut bears nuts at the tip of current year shoots (Funk 1978),we assumed that the nut yield is in proportion to the surface area of the crown. Nut yield for trees in alternative 2 therefore can be calculated by (Nut yield for trees in alternative 1)(Crown surface area for trees in alternative 2)/(Crown surface area for trees in alternative 1). The crown surface area was calculated by using a paraboloid solid model (Husch et. al. 1972):

$$\text{Area}= \left(\frac{2\pi r}{12h^2}\right)\left((r^2+4h^2)^{3/2}-r^3\right) + \pi r^2$$

where r is the crown diameter and h is the crown height,which is computed as the difference between total height and pruning height. The simulated nut yields for both alternatives from age 20 through age 80 at the interval of 5 years are presented in Table 3.

Revenues estimation

Prices for black walnut timber were averaged over the four-year period from 1974 to 1978 (Lott and Park 1975, Hoover 1979). Because of the difference in price between select grade and prime grade of veneer logs, we used the percentage of grade yield proposed by Schlesinger (1978) as weights to calculate value of the log at various diameter classes. An example of valuation of thinning yields for alternative 1 is given in Table 4. Other valuations were calculated in a similar manner. An average price of $4.38 per 100 pounds of delivered husked fresh walnuts was used to calculate revenue from nut yield. The price was derived from average prices paid by Hammons Products Company of Stockton, Missouri from 1974- to 1977.

Cost estimation

Fixed costs per acre included land purchase ($350), road and fences establishment ($70). , cultivation and site preparation ($35), planting material and labor ($25),weed control for three years($90), corrective pruning for

Table 2.--Simulated thinning yields and harvest cut for black walnut at various ages

Age (years)	Average d.b.h. (inches)	Number of trees cut per acre	Volume cut (board feet)			
			Alternative 1		Alternative 2	
			per tree	per acre	per tree	per acre
23*	9.3	26	9	234	9	234
28*	11.1	27	17	459	22	594
36*	13.8	13	35	455	46	598
40	15.2	40	45	1800	62	2480
44*	16.5	12	57	684	78	936
45	16.8	28	60	1680	83	2324
50	18.4	28	77	2156	107	2996
55	20.0	28	95	2660	135	3780
55*	20.0	7	95	665	135	945
60	21.6	21	116	2436	165	3465
65	23.3	21	140	2940	201	4221
66*	23.6	6	145	870	208	1248
70	24.9	15	165	2475	238	3570
75	26.5	15	192	2880	278	4170
80	28.1	15	221	3315	321	4815

*thinning yield

Table 3.--Simulated nut production for black walnut at various ages

Age (years)	Crown surface square feet (per tree)	Crop weight pounds (per tree)	Crop weight pounds (per acre)	Crown surface square feet (per tree)	Crop weight pounds (per tree)	Crop weight pounds (per acre)
	- - - Alternative 1 - - - -			- - - - Alternative 2 - - - -		
20	2059	--	---	1712	--	----
25	2817	9	733	2414	8	628
30	3698	21	1105	3233	18	966
35	4537	31	1624	4021	27	1439
40	5449	41	1656	4878	37	1482
45	6356	52	1444	5734	47	1303
50	7288	62	1733	6615	56	1573
55	8242	72	1519	7519	66	1386
60	9216	83	1742	8444	80	1596
65	10259	93	1963	9434	86	1805
70	11271	103	1548	10397	95	1428
75	12300	113	1694	11377	104	1566
80	13344	123	1839	12374	114	1705

Table 4.--Valuation of thinning yields for alternative 1

Age (years)	D.I.B. (inches)	Board feet (per acre)	Grade	Grade yield (percent)	Price dollars per thousand (board feet)	Revenue dollars (per acre)
23	8.3	234	Number 3c	100	180	42.12
28	9.9	459	Number 3c	100	180	82.62
36	12.3	455	Number 2c	100	260	118.30
44	14.7	684	Number 1c	100	378	258.55
55	17.8	665	Select	55	1828	668.59
			Prime	45	2501	748.42
66	21.0	870	Select	40	1828	636.14
			Prime	60	2501	1305.52

three times ($30). Bole prunning costs were $22 for pruning to 4 feet at age 5 and $33 for pruning to 9 ft at age 10. As to alternative 2 which emphasizes timber production by pruning to 17 feet at age 17, additional $50 was assessed.

Fixed annual costs including taxes and maintainence were set at $10 per acre per year. The variable cost for nut collection was $5 per thousand pounds and the cost for timber harvest was $55.5 per thousand board feet.

DISCOUNTED NET WORTH

The first approach used to compare the economic efficiency of two alternatives is by discounted net worth which is expressed as a dollar figure at a given discount rate. It is also easily manipulated to reflect changes in input value. However, it is sensitive to discount rate for which different estimates give widely different solutions to the same set of input data. The discount rate used in computing present net worth was 6.75 percent which represents the average rate of inflation for the United States from 1971 to 1976 (Hoover 1977).

It can be seen in Table 5 that alternative 1 which emphasizes nut yield by pruning to 9 feet of clear bole yields a higher discounted net worth than alternative 2, which emphasizes timber yield by pruning to 17 feet of clear bole. The reader should not be alarmed at the negative values for discounted present net worth because in our calculation revenue returned from land sale was not included. Furthermore, we have not adjusted timber or nut price increases due to inflation for future timber or nut sales. These two conditions may not be realistic but it would not change the result of comparison between two alternatives unless the relative rate of price increase for the two products differs significantly. In fact, any changes in costs and revenues which are common to both alternatives will have no effect on the outcome of choosing the best alternative. For example, the maximum difference of $148.47 was found between the two alternatives at age 55. If we assume that the present net worth for land is $500 per acre, then the present net worth of a black walnut plantation, including land, for alternative one is 500-81.50=418.5, and for alternative two is 500-229.98=270.02. The difference between them is still $148.47.

Similarly, a 10% increase or decrease in cost or revenue values produces only a small change in the difference between two alternatives. The only important factor in selecting the best alternative is the discount rate. Using the optimal rotation age of 55 years for alternative one and 65 years for alternative two, we should choose alternative two for discount rate less than 5 percent, and choose alternative one for discount rate equal to or greater than 5 percent. The reason for this choice is that revenues from nuts can be obtained during the earlier years while the final harvest of timber is at the rotation age. The higher discount factor becomes progressively more important for earlier investment returns.

Table 5.--Discounted net worth (DNW) at 6.75 percent annual compound rate and internal rate of return (IRR) for two black walnut investment alternatives over time

Age (years)	DNW (dollars)	IRR (percent)	DNW (dollars)	IRR (percent)	Differences DNW (dollars)	Differences IRR (percent)
	- Alternative 1 - -		- Alternative 2 - -			
	(1)	(2)	(3)	(4)	(1)-(3)	(2)-(4)
40	-267.03	2.52	-270.43	2.83	3.40	- .29
45	-225.76	3.92	-257.06	3.45	31.30	.47
50	-127.53	5.69	-235.16	4.10	107.63	1.59
55	- 81.50*	6.19	-229.98	4.35	148.47	1.84
60	- 87.33	6.16	-150.76	5.66	63.43	.50
65	- 92.57	6.14	-119.50*	5.96	26.93	.18
70	- 99.47	6.08	-129.88	5.92	30.41	.16
75	- 90.24	6.20	-137.96	5.88	47.72	.32
80	- 98.32	6.14	-146.73	5.84	48.41	.30

*Denotes optimal economic rotation for each alternative

INTERNAL RATE OF RETURN

Internal rate of return is defined as the compound interest rate at which the sum of discounted net returns is equal to zero. It is solved by manipulatating the value of the discount rate in the formula for discounted net worth until its value is approaching zero. The internal rate of return can be compared easily to other investment alternative but is less amenable to adjustment in response to input variations than is discounted net worth.

The highest internal rate of return for alternative one is 6.19 percent at a rotation age of 55 years. For alternative two, it is 5.96 percent at the age of 65 years. Alternative one has a higher internal rate of return than alternative two from 45 years to 80 years. Thus, pruning to increase timber quality is not as profitable as pruning to increase nut yield.

Our study shows that the internal rate of return for black walnut plantations ranges from 2.5 to 6.2 percent, which is low in comparison to a previous black walnut multicropping study (Smith 1973). With additional revenue from fescue seed included by Smith, the internal rate of return was higher than for our alternatives.

CONCLUSION

Judged by present net worth and by internal rate of return, pruning to 17 feet of clear bole with the emphasize on timber production is inferior to pruning to 9 feet with emphasize on nut production, at the assumed cost and revenue structure.

LITERATURE CITED

Ferell, R.S. and A.L. Lundgren. 1976. Mathematical functions for predicting growth and yield of black walnut plantations in the central states. USDA Forest Service General Technical Report NC-24. 5 pp.

Funk, D.T. 1978. The genetics of black walnut (Juglans nigra). U.S. Department of Agriculture, Forest Service Resource Paper WO-10, 13 pp.

Hoover, W.L. 1977. Walnut timber as an investment. Walnut Council Newsletter. Vol. 4, 3:5.

Hoover, W.L. 1979. Walnut log prices. Walnut Council Newsletter. Vol. 4, 3:5.

Husch, B., C.I. Miller, and T.W. Beers. 1972. Forest mensuration. New York: Ronald Press. 410 pp.

Krajicek, J.E. 1966. Growing space requirments. Black Walnut Culture. USDA North Central Forest Experiment Station. pp. 47-49.

Lott, E.J. and E.L. Park. 1975. Price report on indiana forest products. Purdue University Cooperative Extension Service. 2 pp.

Naughton, G.G. 1970. Growth and yield of black walnut plantations. Kansas State University Extension Service. 11 pp.

Schlesinger, R.C. and D.T. Funk. 1976. Manager's handbook for black walnut. USDA Forest Service, North Central Forest Experiment Station General Technical Report NC-38. 22 pp.

Schlesinger, R.C. 1978. Value gain from thinning. USDA Forest Service Review Draft. p. 14-15.

Schlesinger, R.C. 1975. A tentative stocking guide for black walnut plantations. Northern Nut Growers Association Annual Report. 66:160-162.

Smith, R.C. 1973. Returns from two systems of multicropping. Black Walnut as a Crop. U.S. Department of Agriculture, Forest Service General Technical Report. NC-2. pp. 106-110.

Wylie, J.E. 1966. Nut and wood-dual crops for management. Black Walnut Culture. USDA North Central Experiment Station. pp. 91-94.

Zarger, T.G., R.E. Farmer, and K.A. Taft. 1970. Natural variation in seed characteristics and seed yield of black walnut in the tennessee valley. Southern Conference on Forest Tree Improvement Proceedings. 10:34-40.