WITHIN-ROW CROWDING OF BLACK WALNUT DOES NOT REDUCE THINNING GAINS

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Abstract.--Growing black walnut with a companion agricultural crop (multicropping) is receiving increased interest. This computer simulation study showed that as long as the same number of trees per unit area are included similar potential selection opportunities can be realized from irregularly spaced plantings as from regularly spaced ones.

Additional keywords: *Juglans nigra*, computer simulation, plantation management.

Black walnut (*Juglans nigra* L.) is the most valuable hardwood tree species in the United States. Several theoretical analyses indicate that growing walnut with an agricultural companion crop (multicropping) may be a better investment than growing walnut alone (Callahan and Smith 1974, Kurtz *et al*. 1978). Multicropping generally requires wide spacing between the rows of trees to provide growing space for the companion crop. Thus, these plantings contain fewer black walnut trees per hectare than pure plantings.

Selection thinning makes use of the normal variation in growth rates and quality between trees within a stand or planting. Funk *et al*. (1978) showed that the value of the final crop of trees can be increased if many trees are initially planted and the planting thinned periodically to retain the faster growing individuals, as compared to planting only enough trees to make up the final crop. The wide spacing between rows needed for multicropping results in less selection opportunities, and thus is a disadvantage of this management option.

One way to retain some selection potential and also wide spacing between rows is to decrease the original spacing between trees within the rows. The close spacing within rows might require that thinnings be made earlier than if the same number of trees were planted on a square (regular) spacing. And the irregular spacing would increase the chance that two or more of the better trees would be too close to one another for all to be retained as crop trees. This study was conducted to determine if the potential value gains from selection thinning would be less if a given number of trees were planted at irregular rather than at regular spacings.

METHODS

A computer simulation model was used for the study. The model allows crop trees to be selected from computer-generated walnut populations (Funk *et al*. 1978). Tree size, spacing, and between-tree competition are all considered in choosing the crop trees. The value of the total crop per unit area was used to evaluate and compare the trials for a sequence of original spacings.

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In practice, a series of thinnings would be made before the final crop trees were selected. The crop trees would be the best available trees of all those originally planted, while also giving each tree enough space to develop to its full potential. The computer simulation used the same criteria but made a single selection of the final crop trees from the original population.

Each simulation run used an original population composed of a distribution of random tree diameters, with mean tree diameter of either 41, 46, or 51 cm. Either 1,076 or 538 "trees" per hectare were randomly assigned locations within the "planting". Eight between-row to within-row spacing ratios were tested (table 1), and at least 10 separate simulation runs were made for each of the resulting 48 test combinations.

Table 1.--Between- and within-row spacing (meters)

Between- to within-row spacing ratio	1,076 trees/ha initially		538 trees/ha initially	
	Between row	Within row	Between row	Within row
1:1	3.05	3.05	4.31	4.31
3:2	3.73	2.49	5.28	3.52
2:1	4.31	2.15	6.10	3.05
3:1	5.28	1.76	7.46	2.49
4:1	6.10	1.52	8.62	2.15
5:1	6.82	1.36	9.64	1.93
6:1	7.46	1.24	10.56	1.76
8:1	8.62	1.08	12.19	1.52

The mean values of the runs were used in the analyses. For each run we obtained the average tree diameter and the diameter distribution of both the original population and the selected crop trees plus the total value of the crop trees at the time of final harvest.

RESULTS

An analysis of variance using the value of the final crop per hectare showed that the original number of trees per hectare and the average tree diameter of the original population are significant sources of variation but that the between-row to within-row ratio is not. The increased opportunity for selection in the trials with 1,076 trees per hectare resulted in an increase of 16% in the value of the final crop compared to the trials with 538 trees (table 2). The value of the final crop for the trials using trees initially 51 cm in diameter was 51% more than for those initially 46 cm in diameter and 96% more than for those initially 41 cm in diameter.

Within each of the six original number by original size combinations, the average diameter of the crop trees usually varied only 1 or 2 cm (table 3). Total value varied more (table 2) but there was no obvious pattern to it. Regression analyses of the six data sets yielded no significant trends in value--three showed positive and three showed negative slope coefficients. The simulation process itself results in some variation (experimental error) because only whole trees can be left in a planting and because the available space

Table 2.--Average final value of the trees ($100/hectare)

Original tree diameter (cm)	Between row to between tree distance ratio							
	1:1	3:2	2:1	3:1	4:1	5:1	6:1	8:1
			1,076 trees/hectare initially					
41	125	135	128	121	114	132	127	126
46	217	224	224	231	222	221	201	215
51	332	334	358	327	316	334	360	325
			538 trees/hectare initially					
41	94	96	99	96	101	105	103	100
46	196	187	176	178	184	195	211	204
51	283	304	284	274	280	288	299	326

Table 3.--Average final diameter of crop trees (cm)

Original tree diameter (cm)	Between row to between tree distance ratio							
	1:1	3:2	2:1	3:1	4:1	5:1	6:1	8:1
			1,076 trees/hectare initially					
41	49	50	50	50	49	51	50	49
46	56	57	56	56	57	57	56	55
51	63	63	64	63	62	63	64	63
			538 trees/hectare initially					
41	47	47	47	46	47	48	48	48
46	53	54	53	54	54	54	55	56
51	60	61	60	60	60	60	60	62

within the planting may be used more efficiently in one trial than in another. The average final stocking levels varied slightly (table 4), and this appeared to be associated with the final value of the crop (fig. 1).

The intuitive advantage of regular spacing compared to irregular spacing is that the probability of the best trees being too close to one another for all to be retained as crop trees is decreased. However, comparisons of diameter distributions of the selected crop trees for several of the data sets showed no advantage for the regular spacing. For example, 89% of the crop trees for both the 1:1 ratio and the 8:1 ratio were at least 46 cm tall for the trials with 1,076 trees and original diameter of 46 cm (fig. 2). Indeed, for both spacings, 76% were at least 53 cm in diameter (the mean plus 1 standard deviation.

Table 4.--Average final stocking levels (crown competition factors)

Original tree diameter (cm)	Between row to between tree distance ratio							
	1:1	3:2	2:1	3:1	4:1	5:1	6:1	8:1
			1,076 trees/hectare initially					
41	112	114	113	109	107	109	108	115
46	116	113	114	114	110	106	105	112
51	111	112	119	112	108	114	120	108
			538 trees/hectare initially					
41	107	105	110	113	111	113	110	101
46	120	112	109	106	109	113	120	109
51	111	115	110	107	108	110	113	122

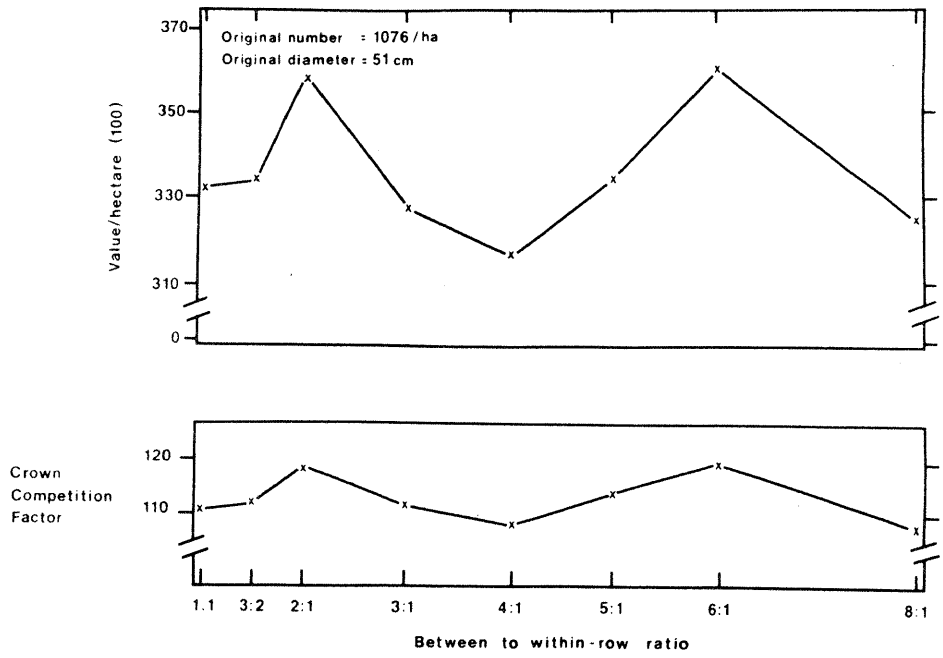

Figure 1.--Variation in value and stocking.

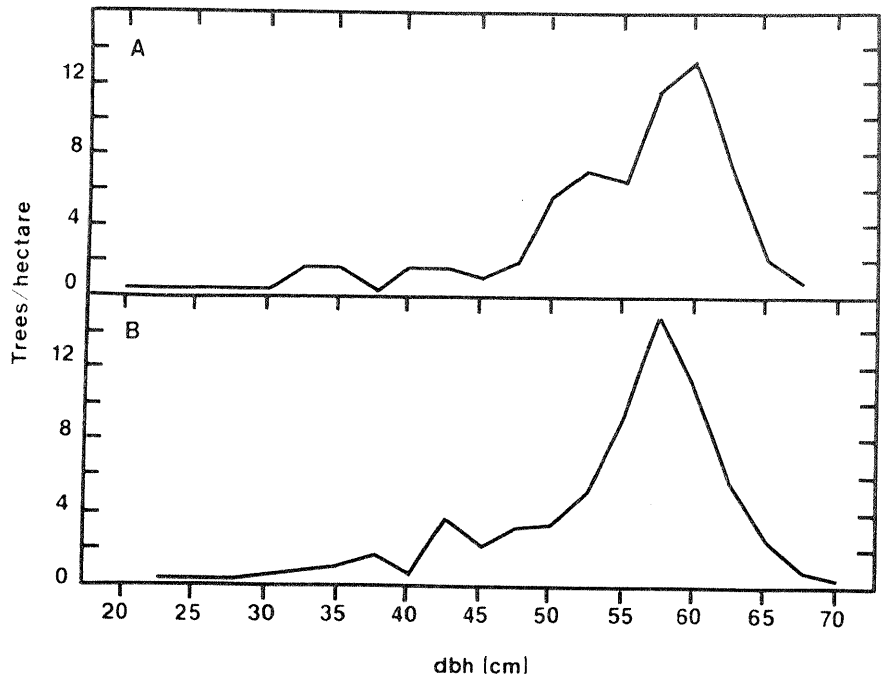

Figure 2.--Crop tree diameter distributions for one irregularly spaced and one regularly spaced planting each with an original population of 1,076 trees/ha. A. Irregularly spaced planting with original within- to between-row distance ratio of 8:1. B. Regularly spaced planting with original within- to between-row distance ratio of 1:1.

DISCUSSION AND CONCLUSIONS

Decreasing the distance between trees within rows increases crop tree selection opportunities of black walnut planted with other crops. However, because this irregular arrangement results in close initial spacing within the rows, the first thinnings will be required when the trees are smaller than those in regularly spaced plantings (table 5).

Table 5.--Comparison of thinning schedules--maximum stocking level = 110 CCF

Original spacing (m)	Original trees/ha.	Diameter at which thinnings are made			
		1st	2nd	3rd	4th
	No.			cm	
3.05 x 3.05	1,076	10.2	16.7	25.9	38.9
8.62 x 1.08	1,076	0.1	5.5	16.5	38.9
4.31 x 4.31	538	16.7	25.9	38.9	
12.19 x 1.52	538	2.4	10.2	25.9	

Preliminary work by Kung (1973, 1974) showed that the correlation of the tree volume at age 30 to the tree volume prior to age 7 is less than 0.50. In practice, then, it may not be possible to recognize as many of the better trees in the irregularly spaced plantings as in the regularly spaced plantings.

If multicropping is a management objective, it appears that planting the walnut trees close together within widely spaced rows will provide the opportunity for increasing the value of the walnut crop through selective thinning. It may not be possible to obtain the full benefits of selection compared with regularly spaced plantings, but neither will it be necessary to give up entirely the opportunities for selection gains in order to produce other crops within the planting.

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