Tree Species Experiment on Afforested Farmland: Experimental Design, Initial Soil Conditions and Tree Growth

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Introduction

A tree species experiment was established to test production capacity of different tree species and tree species mix on land previously used in agriculture, and to study temporal soil changes caused by these trees. A completely randomised block design with three replicates was used.

In terms of experimental design, blocking is the classical field method employed to eliminate some of the experimental residual error caused by field variation. However, in many cases soil variation is not fully considered. Statistically, a basic prerequisite is that variation among blocks is higher than among the experimental units (plots) within each block. If block effect is not significant, nothing is gained from the design but a loss of degrees of freedom for the variation term. In the block design, treatments (tree species) should respond alike in all blocks; however, production levels may be of different magnitude between blocks. Results then refer to a mean value of the measured variable over blocks which may give quite different levels of growth response. Having blocks that are very different is risky, though, for block differences could interact with growth of tree species. There may be different levels of growth, as well as an effect on and response to other investigated variables, for example soil variables.

For an evaluation of soil changes caused by tree species, a design using sites that need blocking may not be optimal. In the blocks, there are no true replicates of treatments and, from the soil perspective, better results might be achieved by treating different blocks as separate experiments. In such field experiments, the site should be homogenous and the design completely randomised. If different soil types are investigated, parallel experiments should be used.

However, if a block experiment has great variation in soil, then the task of evaluating soil response is probably possible. Temporal changes in the soil will be submitted to an analysis of covariance with the initial value as the covariate. The additive main effect—multiplicative interaction (AMMI) model may be used to investigate interactions between tree species and block (Finlay and Wilkinson 1963).

Method

In this completely randomised block design, the six tree species used were *Populus tremula* L. x *Populus tremuloides* Michx; *Alnus incana* L.;

Populus trichocarpa Hook x *Populus deltoides* Bartr.; *Betula verrucosa* Ehrh.; *Alnus incana* mix with *Betula* sp. and *Salix* sp.; and *Alnus incana* mix with *Salix* sp. Among the three replicate blocks, there was a difference in topography between blocks I and II, while soil conditions in blocks II and III were more similar (table 1). In the autumn of 1991, each experimental unit was sampled separately to establish the initial condition at different soil depths. In total, nine depths in the soil profile were sampled, with 20 cores from each soil depth pooled to one sample. For depths from 0-30 cm (A horizon), the soil was divided in increments of 5 cm, and from 30-60 cm (B horizon) in increments of 10 cm.

Samples were dried at room temperature, homogenised and sieved. All analyses were made on soil particles smaller than 2 mm. Soil pH was measured in the supernatant of suspensions with 8 g of soil and 20 ml of deionised water or 0.01 M $CaCl_2$. Exchangeable cations in soil were determined by atom absorption spectroscopy in 0.25 M BaCl extract (Ca^{2+}, Mg^{2+}, K^+, Na^+). Exchangeable acidity (H^+, Al^{3+}) was determined titrimetrically in the 0.25 M BaCl extract. Total organic C and total N were determined by an elemental analyser (Carlo-Erba NA 1500 Series 2).

Height of trees was measured after two growing seasons. In each experimental unit, 42 trees were measured.

Statistical analyses

T-tests were used to assess differences in soil parameters between blocks. To test differences between soil depths within the different blocks, a multivariate analysis of variance (MANOVA) was used, with the different depths in the soil as dependent variables and block as the only factor in the model. MANOVA was used in SAS Version 6.03 (SAS Institute Inc. 1988). The standard error for the difference in properties between depths within the blocks was calculated separately from the computer output of the error variance-covariance matrix (Morrison 1967). The AMMI model was used to investigate interactions between tree species and block (Finlay and Wilkinson 1963).

Results and discussion

Differences in values of soil parameters were present among the blocks. Block I had higher values of organic C and N relative to blocks II and III at almost all soil depths. In the lower part of the B horizon, block III had lower pH values (table 2). Generally, there was a higher concentration of base cations in block I and higher concentration of acidity in blocks II and III (table 2).

Tests of differences in C between depths within the blocks (table 2) show that the ploughed A horizon is very homogenous; thus

Table 1: Particle size distribution (USDA) in different blocks and horizons

Block	Horizon	Clay	Silt	Sand
I	A	16	41	43
I	B	17	50	33
II	A	13	24	63
II	B	13	27	60
III	A	13	32	55
III	B	14	23	65

Table 2: Soil parameters and differences in C (between block and between depths)

Block	Depth	C %	N %	pH	Ca^{2+}	Mg^{2+}	K^{+} cmolc/kg	Na^{+}	H^{+}	Al^{3+}
I	0–5	3.778 c A	0.24 A	6.5 A	16.1 A	1.13 A	0.35 A	0.16A	0.38 A	0.04A
	5–10	3.996 b A	0.244 A	6.6 A	17.0 A	1.22 A	0.35 A	0.15 A	0.36 A	0.03 A
	10–15	4.157 a A	0.250 A	6.6 A	-	-	-	-	-	-
	15–20	4.101 a A	0.259 A	6.6 A	-	-	-	-	-	-
	20–25	4.046 ab A	0.249 A	6.7 A	-	-	-	-	-	-
	25–30	2.978 d A	0.195 A	6.7 A	-	-	-	-	-	-
	30–40	0.864 e A	0.062 A	6.9 A	9.9 A	0.89 A	0.23 A	0.14 A	0.40 A	0.04 B
	40–50	0.449 f A	0.029 A	7.2 A	-	-	-	-	-	-
	50–60	0.585 e A	0.024 A	7.5 A	-	-	-	-	-	-
II	0–5	1.409 bc B	0.121 B	6.7 A	8.0 B	0.67 A	0.41 A	0.10 B	0.43 A	0.03 A
	5–10	1.448 abc B	0.127 B	6.8 A	8.4 B	0.68 A	0.36 A	0.08 A	0.42 A	0.03 A
	10–15	1.506 abc B	0.122 B	6.8 A	-	-	-	-	-	-
	15–20	1.496 a B	0.128 B	6.8 A	-	-	-	-	-	-
	20–25	1.447 abc B	0.117 B	6.8 A	-	-	-	-	-	-
	25–30	1.139 c B	0.097 B	6.6 A	-	-	-	-	-	-
	30–40	0.620 d A	0.0545 B	6.2 B	4.3 B	0.47 A	0.26 A	0.09 B	0.75 A	0.18 B
	40–50	0.354 d A	0.0222 A	6.0 B	-	-	-	-	-	-
	50–60	0.261 d B	0.0157 A	6.0 B	-	-	-	-	-	-
III	0–5	1.485 b B	0.129 B	6.7 A	7.6 B	0.81 A	0.40 A	0.09 B	0.32 A	0.04 A
	5–10	1.535 a B	0.134 B	6.8 A	8.3 B	0.86 A	0.40 A	0.12 A	0.31 A	0.02 A
	10–15	1.503 a B	0.114 B	6.8 A	-	-	-	-	-	-
	15–20	1.584 a B	0.133 B	6.6 A	-	-	-	-	-	-
	20–25	1.486 a B	0.113 B	6.7 A	-	-	-	-	-	-
	25–30	1.068 c B	0.090 B	6.4 A	-	-	-	-	-	-
	30–40	0.624 d A	0.053 B	5.7 B	4.3 B	0.55 A	0.29 A	0.09 B	1.28 A	0.41 A
	40–50	0.365 e A	0.023 A	5.3 C	-	-	-	-	-	-
	50–60	0.267 e B	0 0009 B	5.3 C	-	-	-	-	-	-

Letters show statistically significant differences ($p<0.05$): capital letters refer to differences between blocks and lower case letters refer to differences between depths

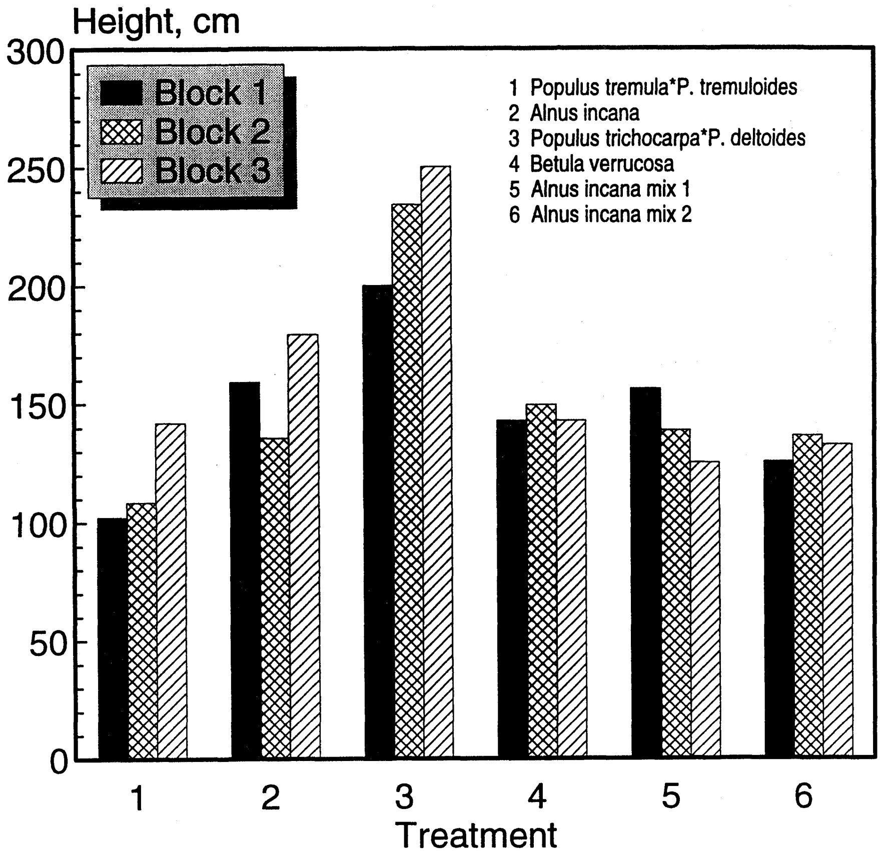

Figure 1: Variation in tree height (cm) between blocks.Interactions between tree species and block could not be shown statistically (p>0.1)

soil development caused by the new tree crop may be detected accurately in the future. The structure of variance among depths in block III seems to be somewhat lower.

Height of trees differed between species (figure 1). No interaction between tree species and blocks could be detected statistically with the AMMI model (p>0.1). Such interactions may not be clear until after two growing seasons. In the future, interactions will be tested throughout the evaluation, and interactions of soil responses with block will also be tested. Soil changes will be tested after four years, with focus on the top 5 cm of the soil.

References

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