PRODUCTION IMPROVEMENT OF *CORDIA ALLIODORA* (RUIZ & PAVON) OKEN PLANTATIONS IN LOWLAND TROPICS OF ECUADOR

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Abstract

Initial growth of *Cordia alliodora* (Ruiz & Pavon) Oken was analyzed in polyclonal production plantation within the tropical moist forest life zone in the coastal region of Ecuador. Permanent research plots (PRP) were of line design and comprised initial number of 25 trees of each clone. In total 79 different clones were planted; these were selection from four main groups of ortets. The highest mean height value (5.37 m) at the age of 1.2 years was shown by the groups of samples A and R at bottom relief type. The minimum height was 2.88 m for group P at top relief type. This minimum represents only 54% of the maximum mean height for group P at bottom relief type. A multiple linear regression equation was performed to predict tree height using group of clones, tree age and relief type as independent variables. The highest contribution of tree age to the predicted model was confirmed. Relief type has a higher influence on height than the group has. Further applications for management improvement are discussed.

Key words: *Cordia alliodora*, Laurel, Salmwood, clone, plantation, growth, relief

INTRODUCTION

The forestry sector in Ecuador has the potential to satisfy local demand for wood products; nevertheless the potential of forest plantations is until now almost unused. It is estimated that at least 1 million hectares of forest land are suitable for forest plantations, but only 164 thousands of productive plantations are established in the country (FAO, 2005). In future most of new plantations will be established for industrial purposes which might also decrease the pressure on native forests. *Cordia alliodora* (commercially known as Laurel or Salmwood) is an important plantation species. It has proved itself to be one of a small number of species that can be generally planted in the lowland tropics. It remained healthy under plantation conditions over 20 years (Alder and Montenegro, 1999). It grows naturally from northern Mexico, through Central America and South America, to Paraguay, southern Brazil, and northern Argentina (Greaves and McCarter, 1990). In Ecuador *C. alliodora* is native to the lowland tropical forests both east and west of the Andean Cordillera. It commonly occurs to altitudes up to 900 m asl, with occasional individuals being found up to 1200 m, and is found in rainfall zones varying from 1000 mm to 4500 mm per annum (Montenegro and Veloz, 1999). Its timber proprieties are comparable to *Swietenia macrophylla*, *Tectona grandis* and *Juglans regia* (Hummel, 2000). In Ecuador, it has been extensively planted for timber production by the Fundación Forestal Juan Manuel Durini (FFJMD), which also assisted private growers to plant additional areas. The wood is valuable for decorative veneers and quality joinery timber and has a strong international market. It is worldwide used both in pure plantations and as a cover crop for coffee and cocoa (Alder and Montenegro, 1999). Information on the species has been newly reviewed from several aspects. Growth patterns have been analyzed by Hummel (2000) and Menalled et al. (1998), Cole and Ewel (2006) evaluated allometric equations, and possibilities of vegetative propagation are discussed in Mesén et al. (1997). Its medicinal effect is confirmed in Kloucek et al. (2007). Greaves and McCarter (1990) reviewed general information on the species. Dendroecological analyses in the conditions of central Panama were carried out by Devall et al. (1995). It is widely accepted that it is inefficient to establish Laurel plantations on poorer sites. The rotation for maximum production increases rapidly with decreasing site index, from 5–6 years on the best sites, to more than 20 years on the poorest sites. At a site index of 24 and stocking of 300 trees per ha, mean annual increments to 10 cm overbark and 20 and 35 cm underbark are approximately 17, 9 and 4 $m^3.ha^{-1}.y^{-1}$, respectively. There is therefore a very strong incentive to process the smallest diameter material possible (Alder and Montenegro, 1999). As noted above, Laurel is sensitive to site and requires the development of some method of site selection to avoid planting in unsuitable locations. Laurel does not show a strong diameter response to wide spacings, unlike wider crowned species, and is naturally slender. Optimum timber yields will therefore be achieved by using higher stand densities than present average values (Alder, 1999; Hummel, 2000). FFJMD started to establish forest plantation of *Cordia alliodora* in 1978 from seed material originating from the eastern and the western part of the country. Seeds were collected from both naturally regenerated trees in farms and artificially regenerated plantations of the highest quality. The aim of the study is to assess the growth potential of polyclonal plantation of *Cordia alliodora* based on first-step measurement as prospect for future evaluations.

MATERIALS AND METHODS

Polyclonal plantation of *Cordia alliodora* (spacing 4 m) was established by FFJMD in area known as Rio Pitzara that lies 420–480 m asl within the tropical moist forest life zone (Holdridge et al., 1971) and receives of around 4000 rainfall per year with the rainy season from January to June. Permanent research plots (PRP) are of line design comprising the initial number of 25 trees. All individuals within one line are of one clone. In total, 79 different clones were planted within the stand in irregular pattern and unequal repetitions. At the time of field measurements the maximum possible difference in age of PRP of the same clone was 0.4 years (0.8 years for the youngest and 1.2 years for the oldest PRP). From the measurement excluded were lines on untypical sites (shadow, compacted soil and stream) and lines, where doubts about the origin of the clone exist. For each tree we registered the diameter at breast height, height and the relief type (top, middle and bottom) since the terrain in the locality is very downy. The tree breeding program of *Cordia alliodora* was initiated in 1994. Forty three plus trees were selected. Open pollinated seeds were used for the seedlings production in the forest nursery. From the selected individuals in 1997 the seed orchard was established. The 79 clones involved in the study are selection from four main groups of ortets: superior offspring selected from plus trees in Rio Pitzara (P) and Rio Sabalo (S) plantations (early mass selection in forest nursery), selected harvested trees from forest stand in Rio Silanches (R) and the second best harvested seed orchard trees (A). Rooted cuttings from adult trees, as well as from seedlings were produced at the Buenos Aires nursery of FFJMD. In this study true identifications of clones are not given, since this was part of the agreement with Fundación Forestal. All statistical analyses were done using Statistica 9.0.

RESULTS

In the first step the relation between stem diameter (diameter at breast height) and height of measured trees was

Figure 1: Scatterplot of Height against Stem diameter of measured trees

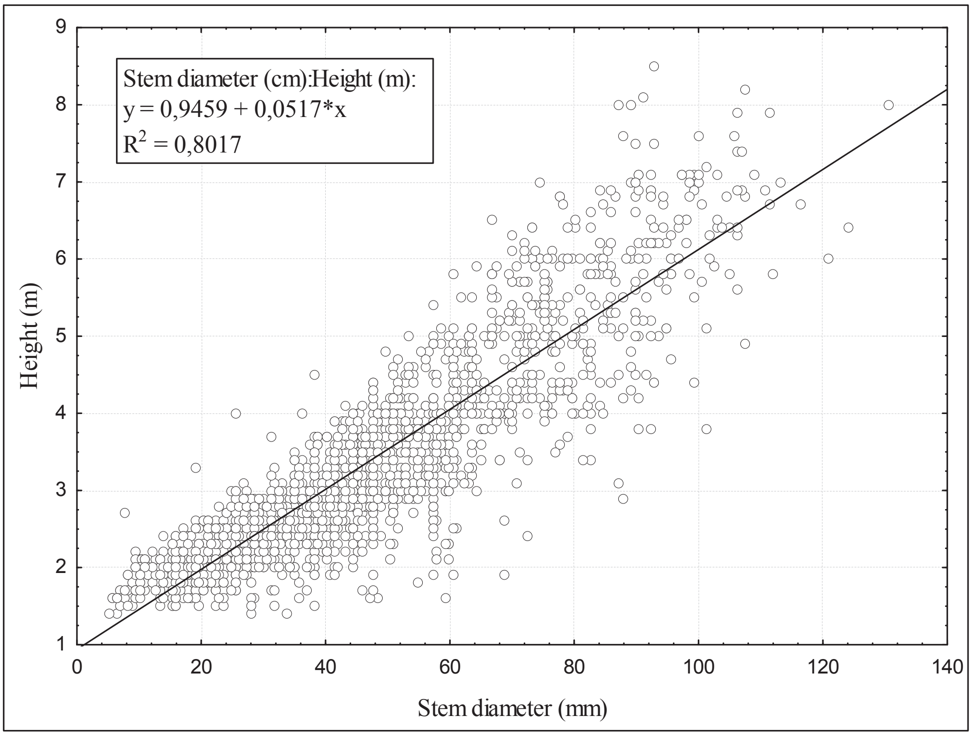


Table 1: Basic descriptive characteristics for heights for groups of clones

Group	Clones N	Valid N	Mean	Minimum	Maximum	SD	CV
A	6	139	3.10	1.5	8.1	1.1422	36.8283
P	14	320	3.11	1.4	8.2	1.1643	37.3890
R	35	984	3.44	1.4	8.5	1.4747	42.8241
S	24	538	3.26	1.4	7.6	1.2902	39.5363

estimated (Figure 1). The database includes 1981 measured individuals on all three relief types and of all ages from 0.8 to 1.2 years. The basic descriptive characteristics of heights for different group of clones are given in Table 1.

The linear function (Figure 1) fitted the data well with a coefficient of determination R^2 = 0.8017. In further comparisons we regarded the tree height as the main parameter. From following analysis we also excluded trees of age other than 1.2 years and trees growing on relief types other than middle (final database included 853 individuals). The basic descriptive statistics were computed: arithmetic mean, the range of data expressed with the maximum and minimum value, standard deviation and coefficient of variation. The assumption of the measured data's normality by a Shapiro-Wilks W test was verified before computing the statistical analysis. Figure 2 shows heights of particular clones reached at the age of 1.2 years on the relief type middle.

There are clear differences in average values and height variations of particular clones. Nonetheless the presented results are of preliminary nature and obviously do not present definitive information about performance of clones. Therefore, and with respect to agreement with FFJMD, in the following part only differences between groups of clones and the influence of other factors on tree growth will be presented. Figure 3 affirms that there are no statistically significant differences between means of height of particular groups of clones.

There is also no statistical difference between average heights of trees originating from different groups of clones. The same analysis was performed for the comparison of h/d ratio. Also in this case no statistical differences were confirmed. (A: h/d = 67.6, P: h/d = 70.4, R: h/d = 67.2, S: h/d = 72.4; not displayed). With respect to relief types following results were obtained (Table 2).

It is shown that the lower value for tree height is reached in top and middle relief types. A decreasing trend for tree height was evident with an increase in terrain elevation. The highest average height (5.37 m) was shown by the groups of samples A and R at bottom relief

Figure 2: Box Plot of Height grouped by Clone (age 1.2 year, relief middle)

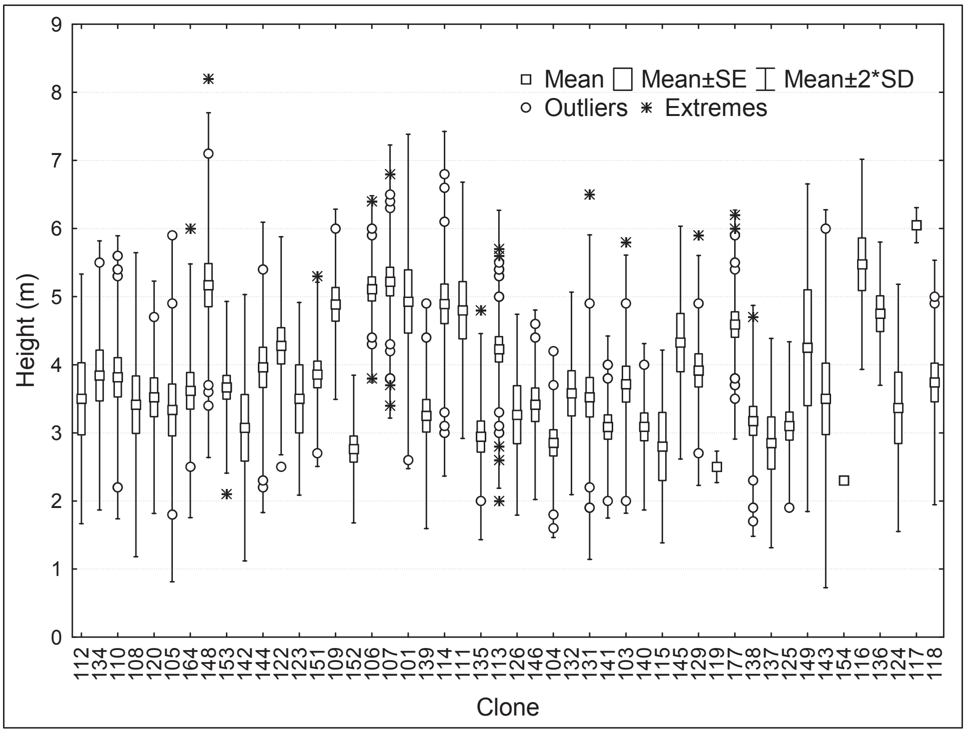
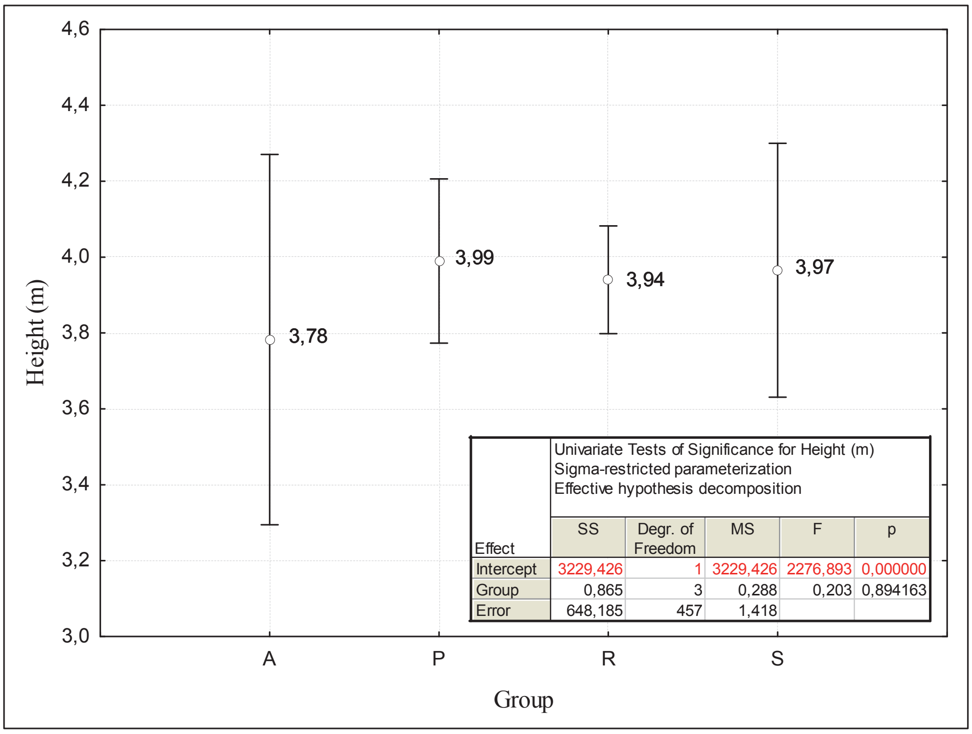


Figure 3: Average heights of groups of clones (age 1.2 years, relief middle). Vertical bars denote 0.95 confidence intervals



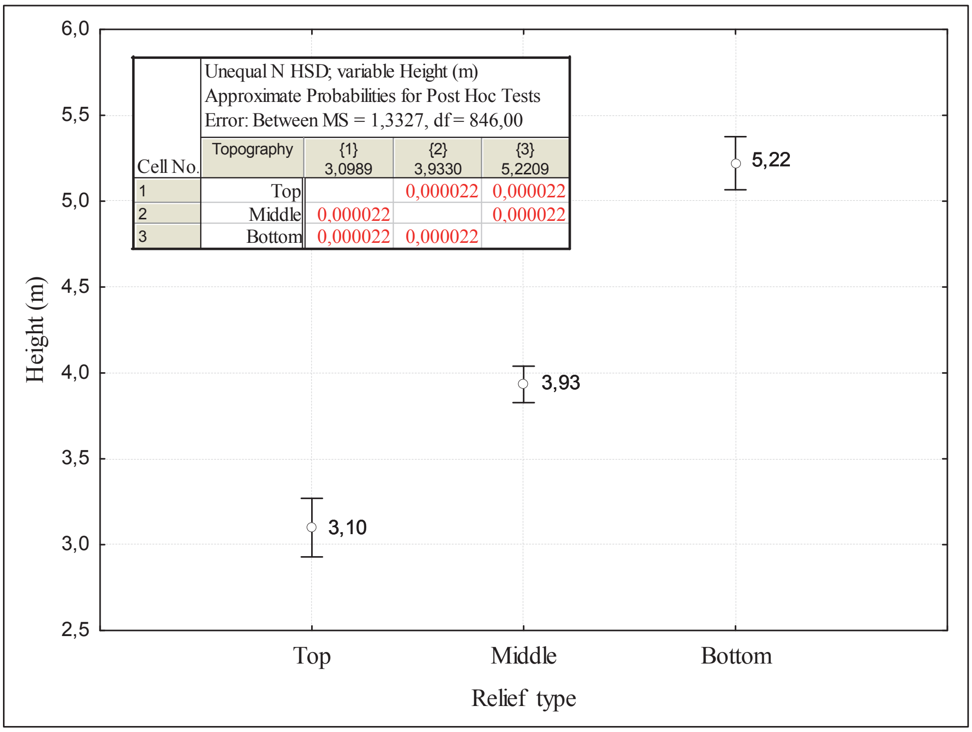
type. The minimum height was 2.88 m for group P at top relief type. This minimum represents only 54% of the maximum mean height for group P at bottom relief type. To determine significant differences between means in different relief type the analysis of variance (ANOVA) and multiple comparison test (Tukey HSD test) were used (Figure 4).

The multiple comparison test demonstrates a significant difference between heights for all relief types. Relief type is factor with higher impact to growth performance than group. Multiple comparison test also confirmed significant difference of h/d ratio on bottom relief type (Bottom: h/d = 71.8, Middle: h/d = 68.6, Top: h/d = 68.1). The tree reacts to better site conditions by increased height and diameter increment; nevertheless the response of height growth is stronger or at least faster than that of diameter. A multiple linear regression equation was performed to predict height (h) using group of clones (g), tree age (a) and relief type (t) as independent variables. Beta coefficients were used to evaluate the relative contribution of each predictor to the overall prediction of the dependent variable (Beta standardizes variables to a mean of 0 and a standard deviation of 1).

Table 2: Basic descriptive characteristics for heights for groups of clones with respect to relief type

Group	Relief type	Valid N	Mean	Minimum	Maximum	SD	CV
A	Top	19	3.17	1.9	4.7	0.7271	22.9111
P	Top	38	2.88	1.5	4.4	0.7631	26.5045
R	Top	91	3.14	1.8	6.9	0.8005	25.5069
S	Top	29	3.21	2.0	5.0	0.6859	21.3437
A	Middle	23	3.78	2.2	5.6	0.9712	25.6766
P	Middle	117	3.99	1.8	8.2	1.1280	28.2736
R	Middle	272	3.94	1.6	6.8	1.2056	30.5993
S	Middle	49	3.97	1.9	7.1	1.3378	33.7386
A	Bottom	7	5.37	3.5	8.1	1.5808	29.4305
P	Bottom	8	4.71	3.3	6.5	1.0176	21.5939
R	Bottom	131	5.37	2.7	8.5	1.3359	24.8868
S	Bottom	69	4.99	1.9	7.2	1.3737	27.5545

Figure 4: ANOVA and Tukey HSD test: analyses of variance of tree heights on different relief types



$$h = -46.3698 + 0.1458 \times g + 4.4793 \times a + 0.2625 \times t \quad (1)$$

$$R^2 = 0.3279 \quad (2)$$

$$\text{Beta (group)} = 0.090276 \quad (3)$$

$$\text{Beta (age)} = 0.540738 \quad (4)$$

$$\text{Beta (relief type)} = 0.165528 \quad (5)$$

This equation fitted the data with a low coefficient of determination (32.79%). The main reason for relative low value is the fact that we analyzed large number of clones (79) with rather low age variability. Nevertheless, the model presents valuable information about the influence of particular independent variables on the initial growth of clones. The Beta coefficient showed very large contribution of tree age to the predicted model. Relief type has a higher influence on height than the group has.

DISCUSSION

In this study we estimated the production potential of different clones in initial stage of stand development based on single measurement of principal dendrometrical characteristics. The main limitation of this approach is the absence of repeated measurement, which would allow precise estimation of productivity and growth pattern of selected clones. Nevertheless, the results indicated large possibility of growth improvement by selection of the most productive clones. Further testing may show the tree breeding of Laurel to have good silvicultural potential in Ecuador. However, our results also confirmed the importance of adequate site selection (with respect to the relief type that significantly influenced growth conditions already within limited area). Precise estimation of soil conditions was not part of this study, but it is obvious that trees strongly responded to better growth conditions in the bottom of downy terrain. Hummel (2000) stated that the height of *C. alliodora* was significantly associated with tree age and stem diameter, but not with density. Stem diameter decreased with increasing tree density. Results were consistent with competition-density patterns observed in temperate forest trees. These results suggest that the merchantable yield in the low-elevation moist tropics of Atlantic Costa Rica may be increased via stand density management. In this aspect the selection of forest sites appropriate for *C. alliodora* may be even of higher importance. Our observations support the theory that establishment of mixed plantations may be valuable not only from ecological but also economical point of view. Differentiated plantation management (spacing, thinning, rotation period) may further optimize stand productivity and spatial structure.

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