Agriculture, Forestry and Fisheries
2021; 10(5): 183-188
http://www.sciencepublishinggroup.com/j/aff
doi: 10.11648/j.aff.20211005.13
ISSN: 2328-563X (Print); ISSN: 2328-5648 (Online)

The Effect of Mixed Plantation on the Stand Yield and Soil Attributes of *Eucalyptus globulus* and *Acacia decurrens* in North Shewa Zone, Ethiopia

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To cite this article:
Melese Bekele, Lemma Habeteyohannes, Getabalew Teshome, Damtew Ababu, Abeje Tedila, Reta Eshetu, Mesafint Minale, Hailemariyam Fisha, Haile Shiferaw. The Effect of Mixed Plantation on the Stand Yield and Soil Attributes of *Eucalyptus globulus* and *Acacia Decurrens* in North Shewa Zone, Ethiopia. *Agriculture, Forestry and Fisheries*. Vol. 10, No. 5, 2021, pp. 183-188. doi: 10.11648/j.aff.20211005.13

Received: August 3, 2021; **Accepted**: August 19, 2021; **Published**: October 28, 2021

Abstract: Eucalyptus plantation has been playing essential task in narrowing the gap between the supply and demand for wood and wood products in the region. Though eucalyptus is fast-growing and has a better survival rate compared to other exotic species, there is a claim that Eucalyptus species overexploiting the nutrients and water. This consequently led to land degradation and soil fertility decline. Hence, it is important to develop mixed plantations to minimize the gap of monocultures. This study aimed to select *Acacia decurrens-Eucalyptus Camaldulensis* mixed plantation to obtain better woody yield and improve site productivity than sole plantation. *A. decurrens* and *E. camladulensis* seedlings were planted with the proportions of: 0%:100%, 100%:0%, 25%:75%, 75%:25% and 50%:50%. The experiment was set in a randomized complete block design with three replications. Results showed that the tree height and total volume not varied significantly between the mixed and pure stand plantations. Soil nitrogen varies significantly between the treatments. The plantation with 50% *E. camaldulensis* and 50% *A. decurrens* proportion had higher total nitrogen, organic carbon and organic matter in the soil. Lined up with the experiment, the farmers agreed that the 50% *E. camaldulensis* with 50% *A. decurrens* plantations had relatively a better economic benefits and soil improvements. Further inquiry is necessary to know the contribution of each species in soil nutrient addition. Investigation of the mixed plantation of exotic and native species is essential to balance economic and environmental benefits.

Keywords: *E. camaldulensis*, *A. decurrens*, Mixtures, Growth, Yield

1. Introduction

Eucalyptus has more than 500 species. This species is native to Australia, Malaysian region, and the Philippines but, it is planted in a different part of the world since the 1890s [6]. *Eucalyptus* is adaptable to tropical, arid and temperate regions of the world. It is one of the most widely planted trees in the world which covers around 20 million ha of land. It is planted for paper, pulp, fuel wood, timber, amenity plantings and land rehabilitation (Girijashankar, 2010). Plantations of eucalypts (species of *Eucalyptus* and *Corymbia)*, particularly in the tropics and southern hemisphere, have expanded dramatically during the last 100 years [16].

Since the introduction of 55 and more species of eucalyptus grown in Ethiopia, but five up to ten species are widely planted [6]. *E. globulus* performs well in terms of growth and survival rate in highlands and *E. camaldulensis* the second most common *eucalyptus* species of ten grown in lower altitudes [17]. Increasing benefit from eucalyptus is an incentive for farmers to expand *eucalyptus* plantations at the expense of another land uses [8], and also as a result of the availability of high demands for eucalyptus products the trend of expansion of *eucalyptus* plantation on crop and

communal lands have been increasing. The market price for *eucalyptus* poles has grown to be 15 times greater over the last two decades [6].

Though fast-growing and have a better survival rate in degraded lands, there is a concern that mono-cultivation of eucalyptus has caused negative consequence in watershed management, soil and water conservation, wildlife habitat, and recreational values. Hence, to balance this, introducing an improved system could be an appropriate solution.

The mixed plantation is assumed to address more comprehensively the community needs of fuel and construction wood, nutrient cycle and the likes. Besides, different trees or shrub species are not equally affected by adverse environmental factors including drought, disease, and pests, and hence a mixed plantation avoids the risk of total failure or loss. Bauhus, J., Aaron, P., van Winden, and Adrienne B. Nicotra [3] studied that mixed stands of species of similar light demand *(Eucalyptus globules* and *Acacia mearansi)* in Australia and at age of 6.5 found highest stem volume when compared with the mixture of 50% *Eucalyptus globules* and 50% *Acacia mearansii.* This mixture provided 20% more than pure Acacia stand, and more than 120% pure Eucalyptus stand. This showed the necessity of developing mixed plantation to maximize economic benefits and ecologic effects.

Hence, study the best performing mixture of *A. decurrens* and *E. camaldulensis* plantation and comparing with the sole plantation is required to optimize the benefits. The objective of this study is to evaluate effect *Eucalyptus and Acacia* mixed plantation on woody yield, soil nutrient changes and the economic benefits.

2. Materials and Methods

2.1. Site Description

The experiment was conducted in the highlands of North shewa zone, Amhara regional state of Ethiopia. Specifically, the study was done in Merhabite district, which is found in the south eastern part of Debere Birhan at a distance of 160 km south of Addis Abeba (Figure 1). The elevation of the study area reaches about 1931 m.a.s.l, and the average annual rain fall ranges from 968 mm to 1486 mm.

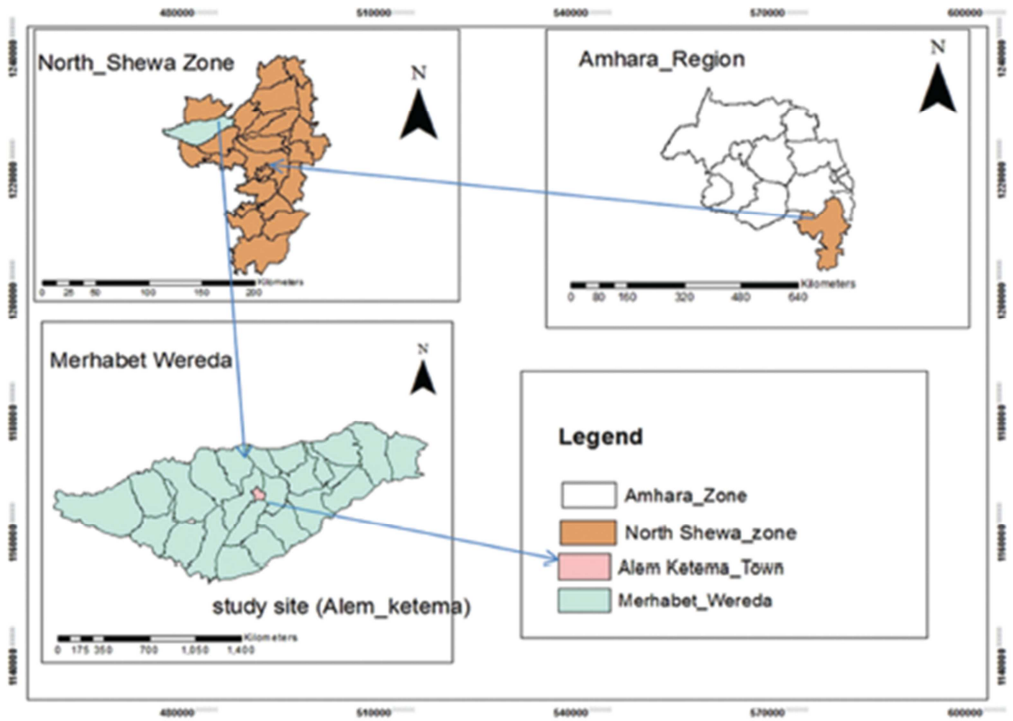


Figure 1. *Map of the study area.*

2.2. Experimental Design

Seeds of *E. camaldulensis* and *A. decurrens* were purchased from Forestry research center (FRC) at Addis Ababa, and raised in Alemketema agricultural office nursery site. The treatments were set both a mixture and sole plantation. The proportions of *Acacia decurrens: Eucalptus camaldulensis* were 0%:100%, 100%:0%, 25%:75%, 75%:25% and 50%:50%. Explicitly, the treatments were *Acacia decurrens* sole plantation, *Eucalyptus camaldulensis* sole plantation, *Acacia-Eucalyptus* mixed (one after the other on alternative rows), *Acacia-Eucalyptus* (three rows of *Eucalyptus* with one row of *Acacia), and Acacia-Eucalyptus* (three rows of Acacia with one rows of Eucalyptus). The treatments were set in a randomized complete block design with three replications.

Each plot had a size of 6m*6m size and the number of seedlings per plots was 16. The spacing between seedlings was 2m*2m. The spacing between blocks and plots were 3 m and 2m, respectively. At the beginning and end of the

experiment, composite soil samples were collected from each treatment at 0-15 and 15.1-30 cm depths. Soil physical properties (moisture content and bulk density) and chemical properties (organic carbon, total nitrogen and electric conductivity) were analyzed following the soil analysis procedures to investigate the difference before and after plantation. The economic effect of the mixed and sole plantation was assessed using the standard procedure. The data used for calculation were labor cost, estimated wood selling price, improvement/deterioration of soil fertility and social data.

2.3. Data

Growth parameters (root collar diameter, diameter at breast height and height), survival count, pest and disease data were collected every six-month interval until the end of the trial. Soil samples were taken at the beginning and end of the experiment. Input cost for (labor, seed purchasing, and management) and estimated the final selling price of the wood.

2.4. Data Analysis

The volume of wood for standing trees was estimated by the following equation: V=0.44*B*H; Where V=tree volume (m^3), B is tree basal area at breast height (m^2) and H is tree height (m). Sample data were analyzed with ANOVA to see the differences among species mean for each variable measured. Least significance difference test (LSD) was used for multiple comparisons when significant differences were found between treatments. Descriptive and other statistical analysis (ANOVA) were carried out using SPSS version 20 software.

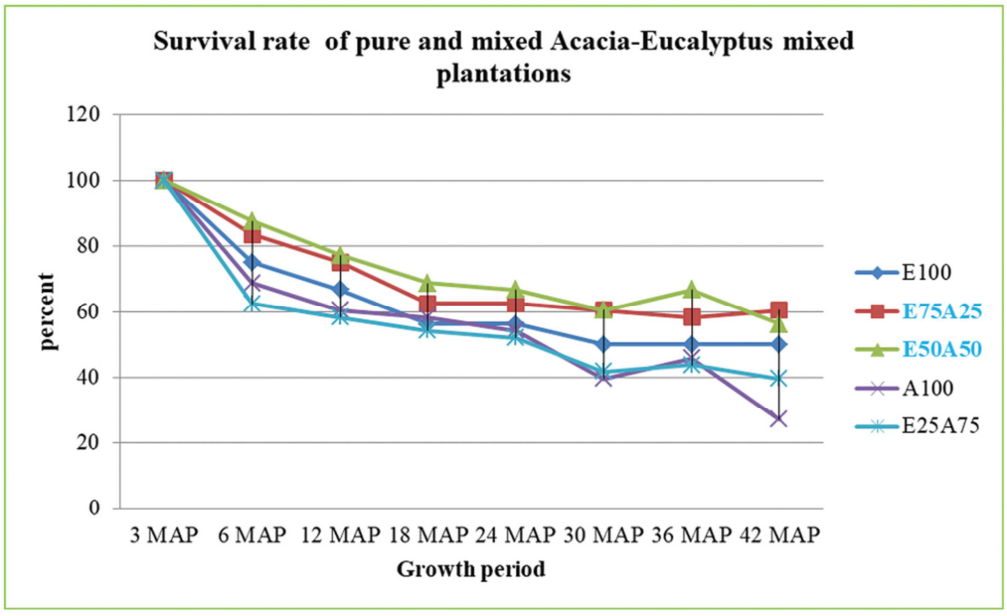
3. Results and Discussions

3.1. Growth Performance

At the age of seven years, the overall mean height was 5.51 (±0.87SD) m. The minimum observed height was 3.93 m and a maximum 7.27 m for Eucalyptus and 50% Eucalyptus proportions, respectively. The mean DBH was 6.33 (±1.44SD) cm ranging from a minimum of 4.6 cm to a maximum of 9.5 cm (Table 1). The wood volume of the total stand was 21.12 m^3/ha with a standard deviation of 1.46 (Table 1) A mix of 75% Acacia with 25% Eucalyptus and 50:50% of Acacia with Eucalyptus had shown a better survival rate compared to other treatments (Figure 2).

Table 1. *The means value of the 7th year Acacia-Eucalyptus plantation trial.*

Parameters	Minimum	Maximum	Mean	Std. error	Std. Deviation
Tree Height (m)	3.93	7.27	5.51	0.225	0.872
Diameter at breast height (cm)	4.60	9.50	6.33	0.372	1.443
Stand Volume (m^3/ha)	7.18	48.31	21.12	3.310	1.460



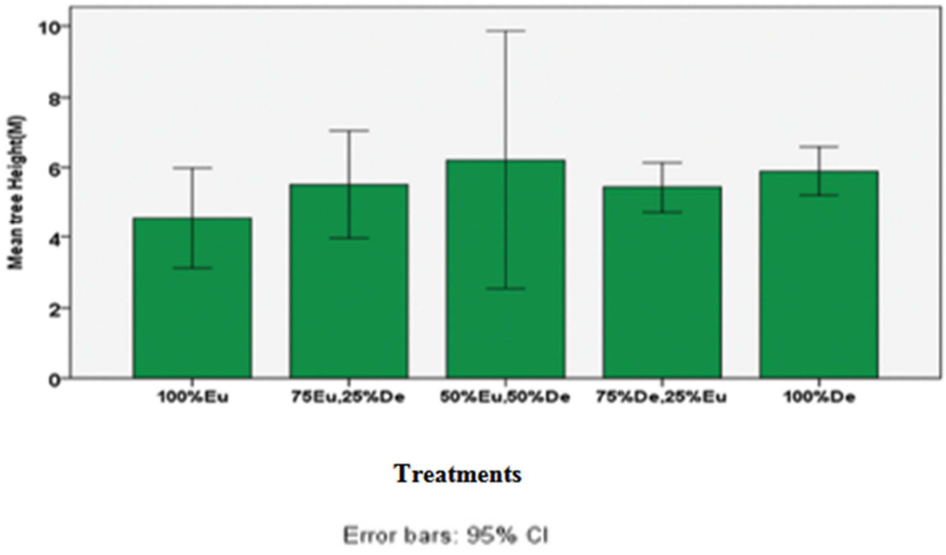
Where: E =*E. camaldulensis*, A=*A. decurrens*, MAP= month after planting.

Figure 2. *The Survival rate of pure and mixed Acacia-Eucalyptus plantation at different month after planting.*

Tree height was not significantly different among pure and mixed plantations (P>0.05) but at the age of 7 years, 50: 50% *E. camaldulensis: A. decurrens* showed the highest mean height (6.1m) growth than other treatments, while pure *E. camaldulensis* had the lowest height (4.6m) growth (Figure 3).

The performance of the tree at the site might be a scribed to the soil conditions, especially poor nitrogen, at the trial site. The prime consideration for mixed plantation is the ecological requirements of species with climate, edaphic and topographic characteristics of the proposed planting site. A careful selection of sites and species is, therefore, critical

for successful establishment and improved growth performance of mixed plantations. Thus, suitable mixtures should provide growth opportunities for each species to result in synergy among them. As the interaction of different species very divergent it is not easy to a generalization about how species will grow in a mixed plantation. However, height-age curves of each species in monoculture [9] and knowledge of the relative shade tolerances of each species should provide a useful basis for species selection.



Where: Eu =*E. camaldulensis*, De= *A. decurrens*

Figure 3. *Bar graph of mean tree height of pure and mixed Acacia and Eucalyptus species at the age of 7 years.*

3.2. Tree Volume

The study showed that tree volume production was not significantly different among a pure and mixed plantation of *E. camaldulensis* and *A. decurrens* species (Table 2), but 50:50% *E. camaldulensis* and *A. decurrens* recorded slightly greater tree volume next to 100% *A. decurrens*. According to a study in Australia, a 6.5 year age of 50:50% E. globules and *A. mearansii* mixed stand found to have the highest stem volume than other treatments, 20% and 120% more than a pure Acacia and Eucalyptus stand, respectively [15].

Table 2. *Mean volume (P=0.05 and Std.Error =7.12) of a pure and mixed stand of E. camaldulensis and A. decurrens at age of 7 years.*

Treatments	Volume (m^3/ha)
100% *A. decurrens*	31.70
75:25%, *A. decurrens*: *E. camaldulensis*	17.49
50:50% *E. camaldulensis* : *A. decurrens*	29.92
75:25% *E. camaldulensis* : *A. decurrens*	16.65
100% *E. camaldulensis*	9.87
Mean	21.12

3.3. Effect of Mixed Plantation on Soil Properties

3.3.1. Soil Depth (0-15cm) Soil pH

The result showed that the soil pH level under *E. camaldulensis* plantation was slightly acidic (6.173) as compared to control marginal land (6.65) and mixed plantation of 25:75% Eucalyptus and Acacia species (6.64) (Table 3). Similarly, Alemie, T. C [1] found reduced soil Ph and strongly acidic values ranging from 3.5 to 4.0 under *Eucalyptus* species plantation. A study by Cao, Y., Fu, S., Zou, X., Cao, H., Shao, Y., and Zhou, L. [4] also showed reduced soil pH, which ranged from 4.2 to 4.5, under *Eucalyptus* species plantations in Koga watershed of Ethiopia. As low soil pH limits the growth and activities of decomposer, the soil biological activities under such monoculture plantation areas are reduced [5].

3.3.2. Soil Organic Matter and Organic Carbon

The organic carbon and organic matter in soils of a mixed plantation of 50:50% *E. camaldulensis* and *A. decurrens* species were moderate than the soils of o the mixtures (Table 3). Pure *E. camaldulensis* and 25:75% *E. camaldulensis: A. decurrens* mix had the lowest soil organic matter and organic carbon. Likewise, Baber, S., Ahmad, M., and Bhatti, A. [2] found that the organic matter content in the surface soil at 0-15 cm depth ranged from 0.38 to 1.10% under *E. camaldulensis*. However, Leite, F. P., Silva, I. R., Ferreira, R., de Barros, N. F., and Neves, L. J. C. [11] found in Brazil that the contents of soil organic matter under *Eucalyptus* plantation were considerably higher than in pasturelands. This implies, *Eucalyptus* plantation also has a potential of increasing soil organic carbon content with time

because lower organic matter inputs can be due to young tree ages [18].

3.3.3. Soil Nitrogen

The result showed that low soil total nitrogen under the trees of both pure and mixed plantations except 50:50% *E. camaldulensis*: *A. decurrens* (Table 3). Tererai, F., Gaertner, M., Jacobs, S. M., Richardson, D. M., Reza ZO, Allahdadi I, Mazaheri D, Akbari GA, Jahanzad E, and Mirshekari M. [12, 13] found that soil total N decreased with an increase in *E. comaldulensis* proportion compared to the site not covered by Eucalyptus species. Similarly, a study by Alemie, T. C [1] in Ethiopia also found that the concentration of soil total nitrogen under the plantations of Eucalyptus species. The increase in N cycling and availability under N-fixing plants can influence the availability of other nutrients, such as P and base cations [10, 14].

Table 3. *Mean values of soil pH, CEC, OC, TN under pure and mixed plantation (soil depth: 0-15cm).*

Treatments	pH	CEC	OC (%)	OM (%)	T.N (%)
100% *E. camaldulensis*	6.17	0.108	2.683	4.672	0.160
75:25%, *A. decurrens*: *E. camaldulensis*	6.39	0.125	2.694	4.633	0.140
50:50% *E. camaldulensis* : *A. decurrens*	6.33	0.157	3.240	5.572	0.200
75:25% *E. camaldulensis* : *A. decurrens*	6.56	0.132	1.705	2.930	0.130
100% *A. decurrens*	6.51	0.125	2.659	4.570	0.157
Control	6.47	0.112	1.609	2.773	0.040
Mean	6.41	0.127	2.437	4.191	0.137
Std.Error	0.15	0.013	0.613	1.053	0.021
Sig (5%)	ns	ns	ns	ns	***

Where: E. =Eucalyptus camaldulensis, A. =*Acacia decurrens*, CEC=Cation Exchange Capacity, OC=Organic Carbon, TN=Total Nitrogen and OM=organic matter.

3.3.4. Economic Returns of Pure and Mixed Plantation

The price of tree products at immediate harvest was estimated by evaluating the market prices each treatment by participating in the local community. Whereas the costs of tree management was calculated by considering the major management activities and it was similar for all treatments. According to this result, the 50:50% *E. camaldulensis*: *A. decurrens* generated more money than others. It has high marginal net benefit and was a combination profitable treatment (Table 4). A study was conducted in central Ethiopian highland in 2008 to investigate the consumption of house construction wood, the tree species preference for construction wood and the forthcoming conditions of this forest product and possible strategies for future avail-ability in line with this study [7].

Table 4. *Estimated cost-benefit analysis of each treatment at the final 7th -year harevest, note all measurements are in Birr/ha base.*

Treatments	The direct benefit from the trees	Indirect benefit (get from grass)	Total gross benefit	Field cost	Net benefits	MNB%
100% Ec	99518.5	6944.4	106463.0	24305.5	82157.4	2.8
75:25%, Ec: Ac	69333.3	6944.4	76277.7	24305.5	51972.2	
50:50% Eu: Ac	102111.0	6944.4	109055.5	24305.5	84749.9	2.9
75:25% Eu: Ac	70166.7	6944.4	77111.1	24305.5	52805.5	
100% Ac	46370.7	6944.4	53314.8	24305.5	29009.2	
Average	77500.0	6944.4	84444.4	24305.5		

Where: Ec=*E. camaldulensis*, Ac=*A. decurrens*.

4. Conclusion

In conclusion, pure stands of *E. camaldulensis* and *A. decurrens* plantations showed the lowest survival and growth performance than mixed plantation. The tree height and total volume did not show a significant difference between the mixed and pure stands. However, mixed plantation resulted in improvement of soil nutrients. A mix of 50:50% *E. camaldulensis: A. decurrens* plantations scored higher total nitrogen than other mixed plantations. In addition, a 50: 50% of *E. camaldulensis* and *A. decurrens* plantations provided better net benefit than other plantations. From this study, a 50:50% *E. camaldulensis* and *A. decurrens*is recommended for mixed plantation thereby to obtain relatively better economic benefits and soil improvements.

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