

Effect of coppicing level and Season on stock volume and new sprouting of Eucalyptus globulus trees in the highland part of Northern Ethiopia

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Abstract

This study was conducted in the *Eucalyptus globulus* tree growing area of Wogera district, North Gondar, Ethiopia. The results showed that there was a significant difference in the mean yield/volume of *Eucalyptus globulus*, ranging from $78.9 \pm 51.3 \text{ m}^3 \text{ ha}^{-1}$ (mean $\pm$ SD) to $148.6 \pm 54.7 \text{ m}^3 \text{ ha}^{-1}$. Coppicing levels, interaction of season and coppicing levels were statistically significant at $p < 0.001$ and $p < 0.05$, respectively. We also found that there was a significant difference in the mean basal area of *Eucalyptus globulus*, ranging from $15.5 \pm 7.7 \text{ m}^2 \text{ ha}^{-1}$ (mean $\pm$ SD) to $21.3 \pm 6.7 \text{ m}^2 \text{ ha}^{-1}$. Coppicing levels, interaction of season and coppicing levels were statistically significant at $p < 0.009$ and $p < 0.006$, respectively. The number of trees per hectare varied from 10682 to 15135 trees ha^{-1} . First coppicing had the highest number of trees per hectare with 18400 trees ha^{-1} , followed by second coppicing level 15135 trees ha^{-1} and third coppicing level 11546 trees ha^{-1} . The number of trees trend showed a decreasing pattern with increasing the level of coppicing. The lowest numbers of trees were found in not coppiced trees. The mean diameter varied from 3.5 ± 0.3 (mean $\pm$ SD) to 4.1 ± 0.5 with the first coppicing level and third coppicing levels, respectively. The results indicated that the mean number of re-sprouts/shoots of the study area varied with different coppicing levels. The number of re-sprouts/shoots increased with the increasing of coppicing level. The highest and the lowest number of sprouts/shoots were Mean 309 ± 87.5 trees ha^{-1} and 223 ± 28.1 in third and the first coppicing levels, respectively.

1. Introduction

Short Rotation Crops (SRC) like *Eucalyptus* plantations has high competence of wood growth in relation to total biomass produced, rapid and reliable sprouting [22]. *Eucalyptus* is a genus of more than 500 species and is one of the best productive tree species because of its desirable characteristics [11, 18]. The name *Eucalyptus* is derived from the prefix "Eu," which means "true," and "calyptus," which means "to cover," and refers to the lower bud, which is composed of joined calyx and corolla components that seal the flower until it blooms [5]. In Ethiopia more than half of its total plantation covered by *Eucalyptus* plantations [4]. In the country, *E. globules* and *E. camaldulensis* are the commonly extensive and survival well in the highlands of Ethiopia [25, 28]. In other countries like Colombia, it was used for reforestation programs [27]. It has well known product and services such as plywood, fuel wood, lumber and environmental conservation [6]. It's coppiced and ability to supply potentially commercial agricultural crop [22]. Introduced *Eucalyptus* varieties *E. globules* was favored tree crop [28]. Nowadays, In Ethiopia, *Eucalyptus* plantation as a form of woodlots is increasing and widely planted in different parts of the country since it has high demand of both fuel wood and construction inputs [19, 3]. With compare to other tree species farmers give high priority to *Eucalyptus* tree species especially for poles, farm implementation, construction and fences [25]. *Eucalyptus* is properly planted with its recommended space and well managed; it can supports and improves and produce highly biomass or yield and soil nutrients status [17, 19]. Since most farmers plant *Eucalyptus globules* for fuel wood production therefore, Yield is very important parameter that used to *Eucalyptus globulus* plantation [22]. Coppicing is a classic way of *Eucalyptus globules* management practices that allows many trees to reshoot from the stump or roots if they are chopped down and saves money compared to replanting the stand [23, 28].

Coppicing is one of the benefits of *Eucalyptus globules* with compared to with other tress species [23] because of its nature-Fast coppicing, *Eucalyptus globules* are suitable an ever increasingly major land use system in the highlands of Ethiopia [26]. Traditionally farmers in Ethiopia has experience in *Eucalyptus globules* coppicing and harvesting yields from different coppicing cycles (first coppicing cycle, second coppicing cycle, third coppicing cycle). Some literatures indicate that tree crops developing from coppice have higher yield compared with seedlings of the same age [20]. Even if farmers harvest yield from different coppicing cycle but the yield were not quantified and not well documents

Unfortunately, since *Eucalyptus globules* introduced and establishment, no adequate information was collected and analyzed with regards to their coppicing cycle, yield or growth rate, coppicing basal area and coppicing volume. Therefore, the aim of this study was First, to assess the effect of coppicing cycle on growth and yield of *E. globules* woodlots at Wogera Districts. To assess the effect of season and coppicing cycle on yield of *E globules* Moreover, this research output can help as a working document for the promotion of appropriate coppicing cycle in the study area as well as in other areas in general.

2. Study area

This study was carried out in one of the potential *E. globules* growing area of Wogera district, North Gondar. It is located 13° 0' 0" N, 37° 40' 0" (Fig. 1).The district has diverse landscapes and its altitude ranges from 1100m to 3040 m.a.s.l [9]. The mean rain fall and the temperature varies from 500–1200 mm and 14–33 degree centigrade respectively [8, 9]. The main vegetation types found in the district are mainly *Eucalyptus*, natural shrubs and acacia species [1]. From the total area of the district nearly 50 percent of the land covered by crop production followed by grazing which accounts 22 percent and forest land 11 percent where as others such as rivers, gorges, buildings share the remaining [10].

2.1. Sampling Design

The study sites were selected based on community *E. globulus* planting and growing experience. Different field equipments were used during field work. For tree (Diameter and height) measurements such as Caliper, meter tapes, hypsometer. To avoid confusion, chalk was used to mark trees. GPS, compass with 360 degree scale (suunto), and tally sheet were used. A total of 120 sample plots (60 from each district) having area having (10m*10m) were selected based on the representativeness of standing population. Data collected and sorted based on four coppicing cycle, or level, without coppicing (0) level, first coppicing (1st) level, Second coppicing (2nd) level, Third coppicing (3rd) level. To make the experiment homogenous and uniform, only *E. globules* trees having three years after planted or coppiced were selected. To capture seasonal variability, two seasons (November and March) were considered. After obtaining one farmer for each *E. globulus* tending operation, the rest was identified by using snow ball sampling techniques. Tree growth parameters such as, diameter at breast height (DBH), height, number of new growing shoots per stump, stump height and stump diameter were measured and collected.

2.2. Data Analyses

Statistical analysis was performing using IBM SPSS version 27. All data were checked for normality test. Analysis of variance (ANOVA) was performed to see significant differences between coppicing levels and seasons on volume, number of trees, basal area and sprouting. Volume of trees was calculated each measured plot and then changed to hectare basis. The following formula was used. Basal area was calculated using the cross sectional area of a tree trunk measured at diameter at breast height (DBH, 1.3 m height) [13].

$$\text{Basal area} = \pi d^2/4$$

Where, $\pi = 3.14$, d = Diameter at breast height in cm

Volume was calculated using the formula

$$V = G \cdot H \cdot F$$

ff = form factor (0.51)

Where, G = basal area ($\pi d^2/4$), H = Height of tree, and F = form factor of tree. Analysis of data was carried out using quantitative methods using R version 3.2.2 software at a significant level of 5%.

3. Result

3.1. Effect of Coppicing cycle/level and season on *Eucalyptus globulus* yield/Volume

A factorial ANOVA was conducted to compare the main effect of coppicing level and season as well as their interaction effects on the yield/Volume of *Eucalyptus globulus* tree. Homogeneity of variances were checked and Levene's results show that the variance of the groups were equal ($F(7, 104) = 0.912$, $p = 0.501$). There was a significant difference in the mean yield/Volume of *Eucalyptus globulus*. Volume ranges from $78.9 \pm 51.3 \text{ m}^3 \text{ ha}^{-1}$ (mean $\pm$ SD) to $148.6 \pm 54.7 \text{ m}^3 \text{ ha}^{-1}$. (Fig. 2) Coppicing levels, interaction of season and coppicing levels were statistically significant at $p < 0.001$ and $p < 0.05$ respectively. Season did not show statistically significant effect on the volume of *Eucalyptus globulus* tree.

3.2. Effect of Coppicing cycle/level and season on *Eucalyptus globulus* basal area

There was a significant difference in the mean Basal area of *Eucalyptus globulus*. It ranges from $15.5 \pm 7.7 \text{ m}^2 \text{ ha}^{-1}$ (mean $\pm$ SD) to $21.3 \pm 6.7 \text{ m}^2 \text{ ha}^{-1}$. (Fig. 3). Coppicing levels, interaction of season and coppicing levels were statistically significant at $p < 0.009$ and $p < 0.006$ respectively. Season did not show statistically significant effect on the basal areas of *Eucalyptus globulus* tree.

3.3. Effect of Coppicing cycle/level and season on *Eucalyptus globulus* Number of trees per hectare

There was a significant difference in the Mean Number of trees per hectare. It ranges from **10682** to **15135 trees ha⁻¹** trees per hectare. First coppicing had the highest number of trees per hectare with **18400 trees ha⁻¹** followed by second coppicing level **15135 trees ha⁻¹** and Third coppicing level **11546 trees ha⁻¹**. The lowest numbers of trees were found in 'not coppiced' trees. The mean diameter varies from **3.5 ± 0.3 (mean ± SD)** to **4.1 ± 0.5** with the first coppicing level and Third coppicing levels respectively.

Table 1
ANOVA model for coppicing levels, season and interaction with Number of trees per hectare

Source	DF	SS	MSE	F value	P value
Coppicing Levels	3	1019833571	349944523.8	42.21	< 0.001
Season of Harvesting	1	3643214.2	3643214.2	0.440	0.509
Coppicing level *Season	3	322223214	107407738.1	12.95	< 0.001
R-Square = 0.61					

Table 2
ANOVA of Number of trees per hectare, Mean Diameter and Height and coppicing levels

Coppicing levels	Number of trees per hectare (N)	Mean Diameter (cm)	Mean Height (m)
Not coppiced	10682.1 ^c	3.7 ± 0.6 ^b	8.4 ± 1.6 ^b
First	18400 ^a	3.5 ± 0.3 ^b	9.1 ± 1.0 ^{ab}
Second	15135.7 ^b	3.6 ± 0.3 ^b	9.0 ± 0.7 ^{ab}
Third	11582.1 ^c	4.1 ± 0.5 ^a	9.7 ± 0.9 ^a
* Mean ± SD			

*Means in columns with similar letters are not significantly different at ($p < 0.05$).

In graph (Fig. 4) indicated that trees harvested in March had higher Mean diameter with compare to trees harvested in November. Generally increasing the number of coppicing levels will increases the mean diameter of the tree except first coppicing levels.

3.4. Number of stump sprout/Shoots, Stump Height and Stump DBH

The result indicated that the mean Number of re-sprout/shoots of the study area was varies with different coppicing level. The number re-sprout/shoots increased with the increasing of coppicing level (Fig. 5). The highest and the lowest Number of re-sprout/ shoots were Mean **309 ± 87.5** trees ha⁻¹ and **223 ± 28.1** in Third and the First coppicing levels respectively. There was not observed statistical differences in the second and the third coppicing levels on establishment of re-shoot in the study area.

Table 3
ANOVA model for Stump Height, stump DBH with coppicing levels, season and interaction

Source	DF	SS	MSE	F value	P value
Coppicing Levels	2	44367.9	22182.9	589.8	< 0.001
Season of Harvesting	1	2040.9	2040.4	54.2	< 0.001
Coppicing level *Season	2	2566	1283.1	34.1	< 0.001
(R-Square = 0.943, adjusted, 0.94)					

Table 4
summary of ANOVA for Stump Height, stump DBH with coppicing levels

Coppicing levels	Stump Height (cm)	Stump DBH (cm)
First	10.8 ± 1.8 ^c	21.7 ± 2.9 ^c
Second	53.4 ± 14.8 ^b	25.5 ± 4.0 ^b
Third	64.0 ± 7.5 ^a	31.3 ± 5.0 ^a
* Mean ± SD		

*Means in columns with similar letters are not significantly different at ($p < 0.05$).

4. Discussion

From our findings, Results indicated that there were significant differences in stand volume between different coppicing levels and harvesting season of *E. globulus* trees in Wogera district, North Gondar Ethiopia. Volume ranges from $78.9 \pm 51.3 \text{ m}^3 \text{ ha}^{-1}$ (mean ± SD) to $148.6 \pm 54.7 \text{ m}^3 \text{ ha}^{-1}$. “Not Coppiced” had shown the lowest stand overall mean volume ($78.9 \text{ m}^3 \text{ ha}^{-1}$) in both seasons (November and March) with compare to other coppicing levels. Similar results also indicated that the ability to coppice and yield from the first coppice crop were higher than the seedling cropping [16]. The overall volume trend indicated that the stand volume increases with increasing coppicing levels first and second levels then decline in the third coppicing level. Similar finding also reported from North shewa by [28]. There

was **69%** and **54.8%** stand volume differences between “Not Coppiced” with first coppiced and Second coppiced respectively. Similar findings also indicated that coppicing crop gives higher yield than a single stem tree [12]

There was a significant difference in the mean Basal area of *Eucalyptus globulus*. It ranges from $15.5 \pm 7.7 \text{ m}^2 \text{ ha}^{-1}$ (mean $\pm$ SD) to $21.3 \pm 6.7 \text{ m}^2 \text{ ha}^{-1}$. Coppicing levels, interaction of season and coppicing levels were statistically significant at $p < 0.009$ and $p < 0.006$ respectively. The result shown that in trees harvested November show statistically significant where as in March there was not statistically a difference between coppicing levels. “Not Coppiced” had shown the lowest stand overall mean basal area ($15.5 \text{ m}^2 \text{ ha}^{-1}$ with compare to other coppicing levels. The first coppicing level had the highest overall mean basal area with $21.321.3 \pm 6.7 \text{ m}^2 \text{ ha}^{-1}$. Our finding was lower basal area compared to *Euclaptus saligna* growing at Taheke forest $25.3 \text{ m}^2 \text{ ha}^{-1}$ reported [15] at 8 years *Euclaptus* planation. The differences may be the difference in stand age. Our finding was Higher with compare to other studies reported by [25] studied in Aboveground biomass, growth and yield for some selected introduced tree species, namely *Cupressus lusitanica*, *Eucalyptus saligna*, and *Pinus patula* in Central Highlands of Ethiopia which was $13.75 \text{ m}^2 \text{ ha}^{-1}$. Mean Number of trees per hectare ranges from 10682 to 15135 trees ha^{-1} trees per hectare. First coppicing had the highest number of trees per hectare with 18400 trees ha^{-1} followed by second coppicing level 15135 trees ha^{-1} and Third coppicing level 11546 trees ha^{-1} . In all coppicing levels, our results shown that the number of trees was higher reported by [15] which was 829 trees per hectare. The lowest numbers of trees were found in ‘not coppiced’ trees. The trend indicated that after first coppicing level it decline with increasing the coppicing levels. After first coppicing the basal area were decreased by 32.6% and 68.1% in the second and the Third coppicing levels respectively.

The result indicated that the mean Number of sprouting/shoots was varies with different coppicing levels. Season were also affected sprouting and sprout numbers [14], the number re-sprout/shoots increased with the increasing of coppicing level. The highest and the lowest Number of sprouting/shoots were Mean 309 ± 87.5 trees ha^{-1} and 223 ± 28.1 in Third and the First coppicing levels respectively. Similar result was reported by [28] the numbers of new shoot were higher in the second and the third coppicing levels studied in north Shewa. We also found statistically difference in both stump DBH and Stump height with different coppicing levels. Stump DBH varies from $10.8 \pm 1.8 \text{ cm}$ to $64.0 \pm 7.5 \text{ cm}$ in the first and the third coppicing levels. Increasing coppicing levels will increase stump DBH and Stump height in the study area. Those stump height has influence in coppicing regeneration [28] since coppice from a bigger stump was faster to grow [24]. Higher stumps have a greater number of epicormics buds and lignotubers, which aids in sprouting [28].

The Pearson's multiple correlation analysis indicated that a strong positive correlation was found between the numbers of new sprouting with stump diameter and stump height ($P < 0.01$, $r = 0.875$) (Fig. 6A). There was also found moderate positive correlation between volume with stump diameter and stump height ($P < 0.01$, $r = 0.425$). (Fig. 6B).

5. Conclusion and recommendation

This study showed that coppicing level and seasons has a major effect on volume, basal area and new sprouting of *E. globulus* trees in Wogera district, North Gondar Ethiopia. The study revealed that stand volume increases in the first and the second coppicing and then it decline in the third coppicing levels. The basal area also showed the same trend of like the volume. The numbers of trees in the first coppicing level were higher than other coppicing levels. The result showed that the number of trees per hectare increased with decreasing its mean Diameter at breast Height (DBH). The lowest diameter at breast height was observed in the first coppicing level 3.5 ± 0.3 (Mean $\pm$ SD) whereas, 3.6 ± 0.3 , 3.7 ± 0.6 and 4.1 ± 0.5 in the second coppicing, not coppiced and Third coppicing levels respectively. In the overall mean trees harvested in March was higher in diameter that harvested in November. The result indicated that new sprouting increases with increasing level of coppicing in the study area. Stump Diameter and Height also showed in increasing pattern with increasing coppicing levels. Strong positive correlation was found between the numbers of new sprouting with stump diameter and stump height.

This study focuses on coppicing level and seasons with its growth related perspectives but the cost benefit analysis with different coppicing levels should be also further studied.

Declarations

Ethics approval and consent to participate:

Not applicable because this article does not contain any plant collection or seed specimens

Data availability:

The dataset used in this paper is available and accessible upon request from the corresponding author.

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Figures

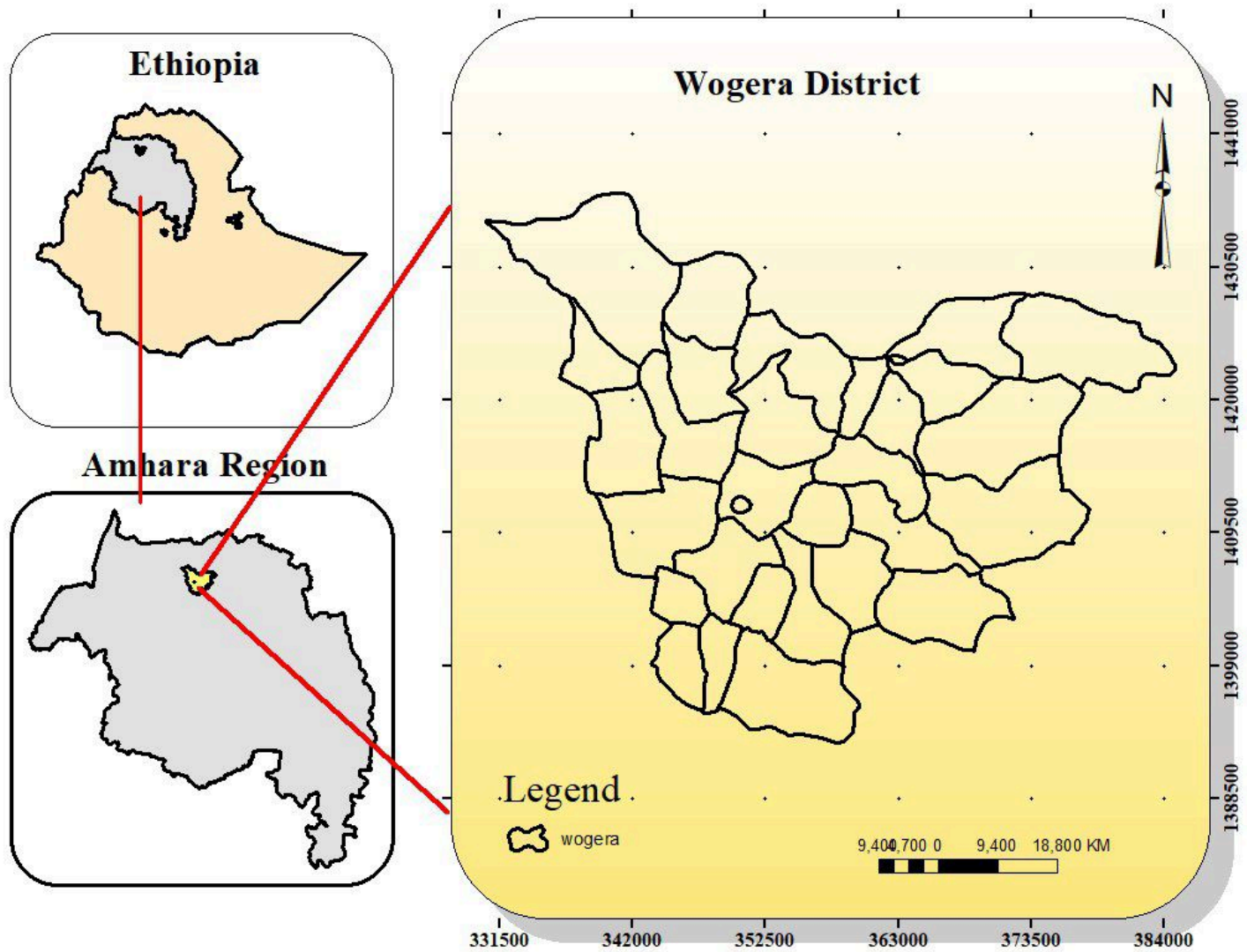


Figure 1

Study area map, Wogera District, North Gondar, Ethiopia

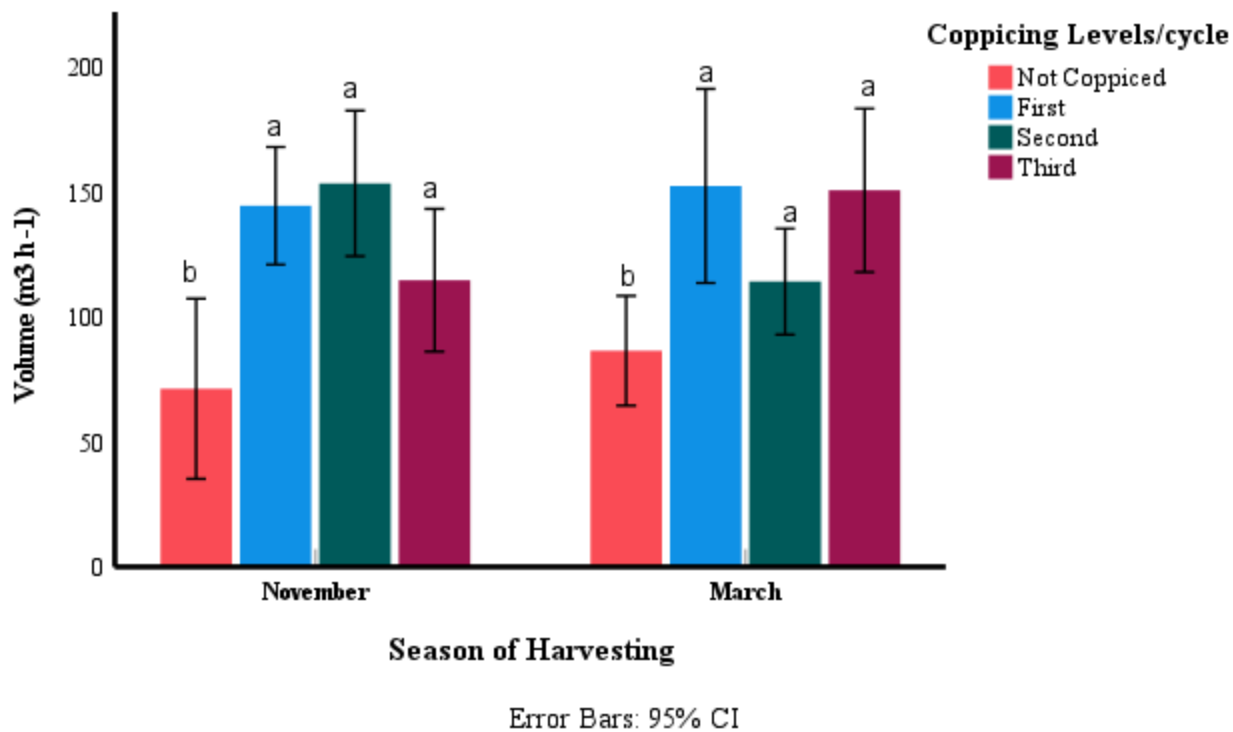


Figure 2

Yield/volume of *Eucalyptus globulus* in four level of coppicing in two season (November and March)
 Significant difference among coppicing levels is represented by different lowercase letters ($p \leq 0.05$).
 Denote statistically significant difference between

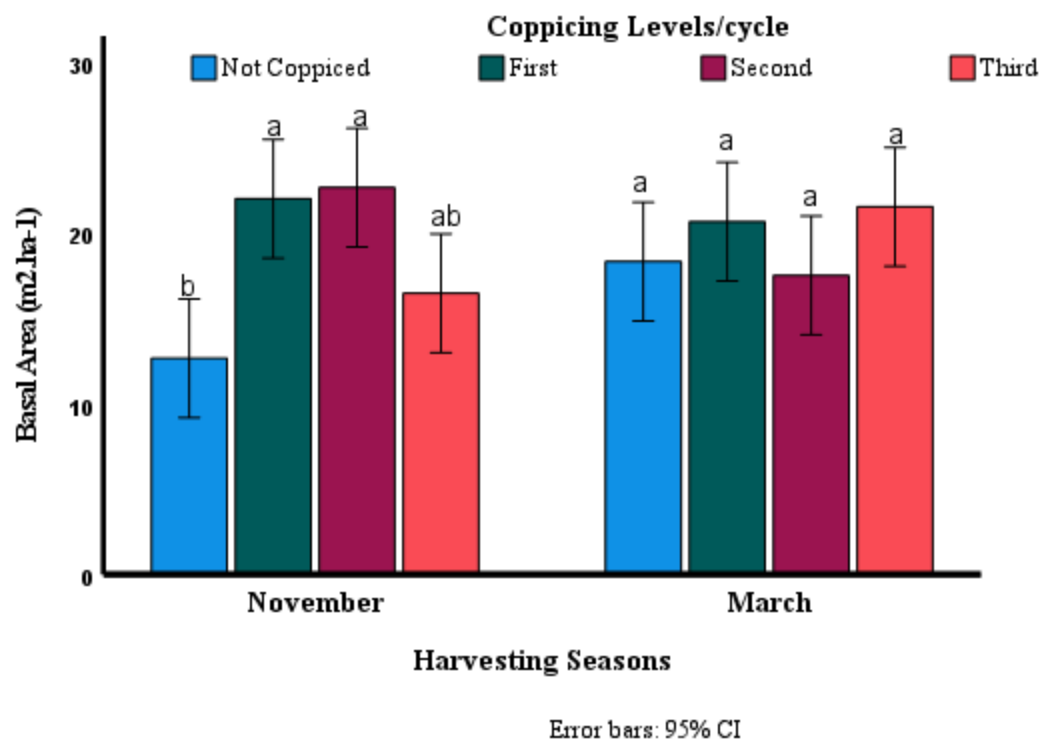


Figure 3

Basal areas of *Eucalyptus globulus* in four level of coppicing in two season (November and (March) significant difference among coppicing levels is represented by different lowercase letters ($p \leq 0.05$). Denote statistically significant difference between

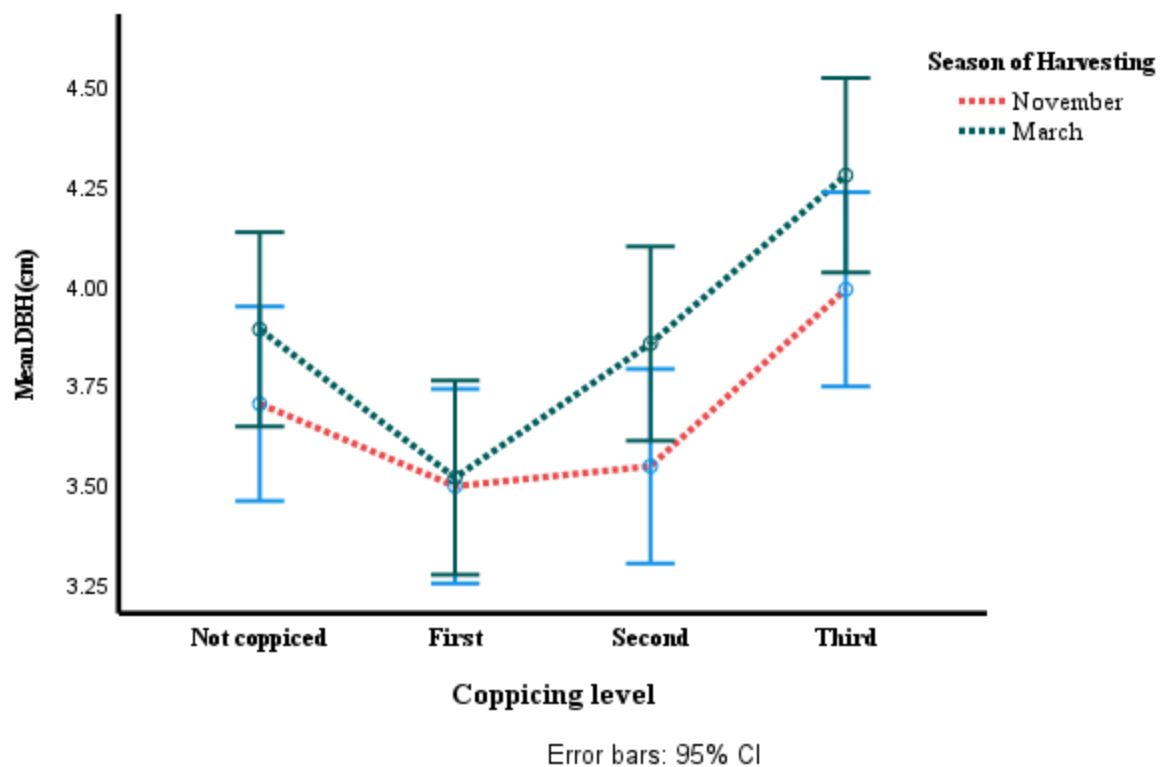


Figure 4

Mean DBH (Diameter at Breast Height) of *Eucalyptus globulus* in four level of coppicing in two season (November and March). Wogera district, North Gondar, Ethiopia

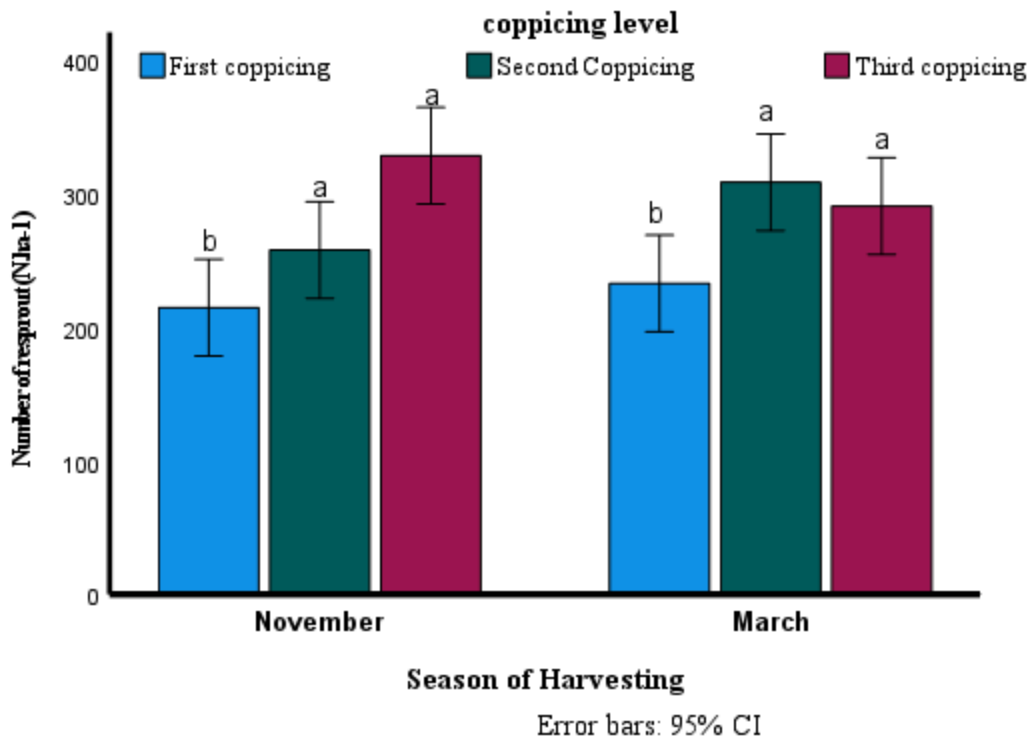


Figure 5

Number of new sprouting/shoots of *Eucalyptus globulus* in four level of coppicing in two season (November and March) Significant difference among coppicing levels is represented by different lowercase letters ($p \leq 0.05$). Denote statistically significant d

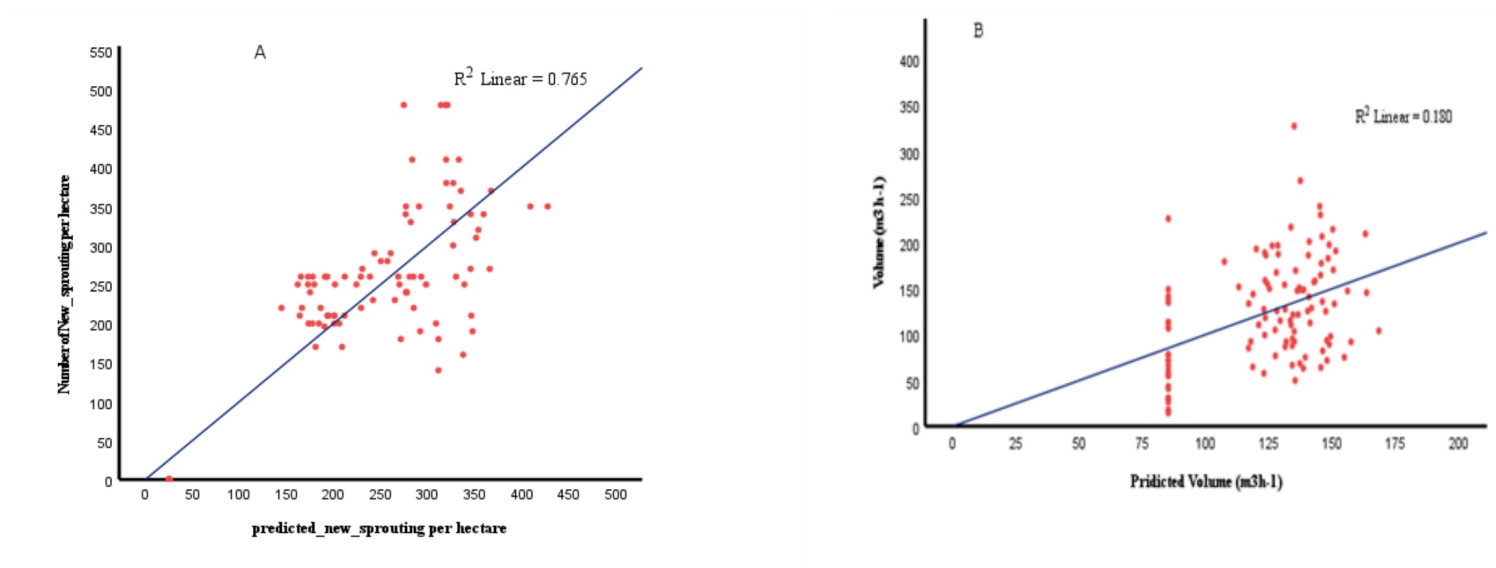


Figure 6

Pearson multiple correlation and linear regression (a) predicted new sprouting per hectare based on stump DBH and stump height (b) predicted volume per hectare based on stump DBH and stump Height of *E. globulus* tree, Wogera district, North Gondar, Ethiopia

