Academic Journal of Plant Sciences 11 (4): 39-43, 2018
ISSN 1995-8986

DOI: 10.5829/idosi.ajps.2018.11.4.39.43

The Influence of Culm Position and Age on Chemical Compositions of *Yushania alpina* grown at Tikur-Enchini in north Part of Ethiopia

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Abstract: The aim of this study was to make comparison of chemical compositions of the indigenous species of bamboo*, Yushania alpina*, which is grown at Tikur-Enchini in the north part of Ethiopia. The experiment has been conducted to determine extractive yield, cellulose content, lignin content and ash content based on the culm position of the bamboo species. Chemical characterization was carried out according to the standard outlined in American Society for Testing Materials (ASTM) except, determination of cellulose content, which was conducted using Kurschner and Hoffer method. The results were analyzed by using Statistical Analysis System (SAS) Software. From the study, it has been shown that the main effect of culm positions on cellulose content and the interaction effect between age and culm positions on cellulose and lignin content is not significantly ($p<0.05$) different. The main effects of extractive yield and ash content with respect to bamboo age and culm position is highly significantly ($p<0.0001$) different. The minimum value of lignin content was obtained at the middle culm position for age 4 bamboo species with value of 27.44%. The maximum yield of extractive contents was found at the bottom culm position for age 5 bamboo with value of 9.95% and minimum extractive content was obtained at the top culm position for age 3 bamboo with the value of 4.71%. The percentage composition of cellulose was found in a range of 43.69% - 49.53% and statistically there is no difference across the culm position. The least ash content was recorded for age 4 bamboo (1.29%) with the yield of 54.09% lower than the maximum. In view of experimental results, it was observed that bamboo culm position, bamboo tree age and interaction of the two factors have distinctly an impact on all chemical compositions (i.e. extractive, cellulose, lignin and ash content).

Key words: Ethiopia · *Yushania alpina* · Cellulose · Lignin · Extractives · Bamboo · Culm Position

INTRODUCTION

Bamboo - is a woody perennial plant species belonging to the family of grasses, Gramineae (Poaceae) with distinctive qualities [1]. It is a self-sustaining, self-regenerating, fast growing species and renewable non-timber natural resource [2] and it has gained a considerable attention as a sustainable and renewable fast growing energy resource with short growth cycles of 4-7 years [3]. The raise in population number with increasing economic development and energy needs has resulted to depletion of other forest resources leading to exploration of bamboo forests for commercial exploitation [4]. Bamboo is well known as a multipurpose plant with a number of applications ranging from: pulp and paper, furniture, construction materials, fence, handicraft, edible shoots and animal fodder [5, 6]. It has been given much attention by governments across the world for its proper utilization since it is plentiful and environmentally friendly [7].

Ethiopia has two main types of bamboo species including: Yushania alpina – covers approximately 31,003 hectares and Oxythenanthera abyssinica – covers about 1,070,198 hectares [6]. Yushania alpina is growing at steeper and higher altitude while Oxythenanthera abyssinica is growing at lowland parts of the country. *Yushania alpina* offers an alternative source of energy because of its fertile regeneration and fast growth besides its wide distributions and previous research work on this bamboo have predominantly focused on mechanical,

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physical and nutritional properties of the species and less on energy potential such that it has been neglected by the bioenergy industry as a potential source of alternative energy [8]. The indigenous bamboo species of Ethiopia, Yushania alpina, is predominantly found in north-western, south-western and central parts of the country. Bamboos are usually well known by high level biomass production per small land area, fastest growth rate and bamboos are environmentally friendly [9]. Seeding and flowering bamboo species are the indispensable means for reproduction and new generations [2] and on the other hand, Ethiopian farmers use the offset method (i.e. the indigenous method) in propagating bamboo species, which is the use of portion of culms and rhizomes [10]. Moreover, bamboo is the most effective in controlling soil erosion mechanism, stabilizing drainage channels, conserving moisture and reinforcing embankments [11] due to its accumulation of leafy mulch and extensive rhizome-root system. The rational of this study was comparison of Culm Position and Age on Chemical Properties of *Yushania alpina,* which is grown in Northern Part of Ethiopia, particularly in the district of Tikur-Enchini.

MATERIALS AND METHODS

Study Area: The study was conducted in Tikur-Enchini, which is one of the districts in the Oromia Region of Ethiopia. Particularly, Tikur-Enchini is located at the Mirab Shewa Zone and it is bordered on the north-east by Ambo, on the north-west by Cheliya, on the south-west by Nono and on the southeast by the Debub Mirab (Southwest) Shewa Zone [12]. Tikur-Enchini is about 72 km away from Addis Ababa, the capital city of Ethiopia and is found in latitude $8^0$44' 59.99" N and longitude 37039'59.99" E and elevation of 2101 meters.

Sample Harvesting and Drying: Samples of bamboo culms were collected from the area of Tikur-Enchini district in April, 2016. The age of culms was estimated based on visual inspection (i.e. color, sheaths in culms and surface lichen growth) by experienced field personnel familiar with the history of the clump. Twelve representative bamboo culms for each age group - namely, three, four and five years old were harvested. The particular sampling technique was previously reported by Li [13]: Internodes were sequentially enumerated from bottom to top for each culms which was then divided into different sections, such as bottom, middle and top, each with an equal number of sections of internodes. The selected internodes from each section and age group were cut into small strips with a razor blade. The strips were dried in an oven drier at 40 °C for 8 h and then, grounded in a Wiley mill equipped with a No. 20 mesh screen. The grounded material was placed in a shaker and particles that passed through a No.40 mesh sieve (425-µm) yet retained on a No. 60 mesh sieve (250- µm). Then, the resulting material was placed in a polyethylene bag according to the experimental setting for further chemical analysis in the study. Twenty seven treatment combinations were used for the study, comprising three levels of bamboo culm positions (top, medium and bottom) and three levels of bamboo ages of (3, 4 and 5 years). During the study the design used for the experiment was completely randomized design (CRD) with three replications [14].

Table 1: Standards followed for chemical analysis

Property	Standard
Cellulose	Kurschner and Hoffer method [15]
Klason lignin	ASTM D1106-56 [16]
Alcohol-toluene solubility	ASTM D1107-56 [17]
Ash Content	ASTM D1102-84 [18]

Characterization of Chemical Properties on Bamboo Species: All tests were conducted under the standards of American Society for Testing Materials (ASTM), except for Cellulose content of *Yushania alpina*. There was a minor modification for extractive content test (i.e. instead of benzene solutions, toluene solution was used). The exact experimental standards that were followed for each chemical property analysis have been presented as per specified in Table (1):

Statistical Data Analysis: The interaction effects of culm position and age on chemical properties were analyzed with SAS software version 9.0 and SAS Studio. The classical general linear model with two-way Analysis of Variance (ANOVA) fits the data very well as shown on the results. Mean separation were carried out using the least significant difference (LSD) at ($P<0.001$).

RESULTS AND DISCUSSION

Variation in Culm Position and Age on Chemical Properties of *Yushania alpina*: Extractive yield and ash content of *Yushania alpina* were highly significantly ($p<0.001$) affected by bamboo culm position, bamboo age and their interaction effects. The values of cellulose content and lignin content on bamboo age were also

Table 2: Analysis of Variance (ANOVA) for chemical properties of *Yushania alpina* grown at Tikur-Enchini.

		Mean square			
Source of variation	*DF*	*Extractive*	cellulose	*Lignin*	Ash
Bamboo Age	2	11.60***	7.05**	5.53**	0.7***
Bamboo Culm Position	2	15.27***	0.45ns	3.07*	1.84***
Age*position	4	2.38***	17.12***	1.23ns	0.46***
Error	18				
CV		3.70	2.18	3.07	5.81
R^2		0.98	0.82	0.62	0.96

***= Significant at $p < 0.001$; ** Significant at $p < 0.01$; *= Significant at $p < 0.05$; ns= Non-significant at p <0.05

DF – Degree of freedom; CV – Coefficient of variation; R – Regression factor

Table 3: Main effects of age and position on Lignin content of *Yushania alpina* grown at Tikur-Enchini

Treatments		Mean Separation Lignin
Bamboo Age	3	28.77[a]
	4	27.44[b]
	5	28.31[a]
Bamboo Culm Position	T	28.49[a]
	M	27.44[b]
	B	28.41[a]

T-Top, M - Middle, B – Bottom

significantly (p<0.001) affected, but the value of cellulose content on culm position and lignin content on bamboo age versus bamboo culm position were noted non-significant effect (Table 2).

The Main Effects of Culm Position and Age on Lignin Content of *Yushania alpina*: The main effects of age and culm positions on lignin content of *Yushania alpina* have shown that highly significant and statistically similar values of lignin content were recorded at the top culm position, 28.49 % and at the bottom culm position, 28.41%. Moreover, the values of lignin content for age 3 and age 5 bamboo species were found to be 28.77% and 28.31% respectively (Table 3). The obtained values were in conformity with previous value reported by *Ireana* [19] in which the percentage value of lignin content in bamboo species (i.e. *B. blumeana*) was comparable with 28.86%. The least lignin content was obtained at the middle culm position of age 4 bamboo (i.e. *Y. alpina*) with value of 27.44%. This value is larger by 19.08% than the result reported previously by *Amsalu* [20].

Interaction Effects of Culm Position and Age on Extractive, Cellulose and Ash Content of *Yushania alpina*

Extractive Yield: The interaction effect of factors (i.e. bamboo age and bamboo culm position) on extractive yield have shown significantly difference (P<0.0001), yielding higher extractive contents, with statistical values obtained at middle (M) and bottom (B) culm positions of 9.22% and 9.95% respectively for age 5 bamboo. Statistically the least extractive content was found at the top (T) culm positions of age 3 and age 5 bamboo with respective values of 4.71 % and 5.79 % (Table 4). The overall obtained mean value of extractive content has revealed significantly higher value of 8.32 % for age 5 bamboo species. This value is in agreement with earlier experimental results reported by *Razak* [21] and is found in the range of 8.00% - 9.23%. The least mean value of extractive content was recorded for age 3 bamboo species (6.06%) which yield 27.16% lower than the maximum value (Table 4) and significantly of higher value when compared with previous studies, such as hardwoods that comprise about 5% extractives, whereas softwoods comprise about 3% extractives [22].

Cellulose Content: As shown in table (4), the interaction effect between bamboo ages and bamboo culm position on cellulose content for *Yushania alpina* is highly significant (P < 0.001). When bamboo ages were observed separately in each culm position (i.e. top, middle, bottom), significantly higher cellulose content (49.53%) was recorded forage 4 bamboo at top culm position, followed by age 3 bamboo with value of cellulose content (48.24%) at bottom culm position. Statistically the least amount of cellulose content was observed on age 3 bamboo species at the top culm position with value of 43.69% and age 5 bamboo at the middle culm position with value of 44.38%. The overall mean value of cellulose content revealed significantly higher and statistically at nominal value of 46.36% for age 3 and 47.09% for age 4 bamboos. The least value of cellulose content was recorded for age 5 bamboo species with the yield of 3.75% lower than the maximum value (Table 4). The percentage compositions of cellulose obtained in this study was ranged between 43.69% - 49.53%, which is in conformity with the other report

Table 4: The interaction effects between age and culm position on chemical compositions of *Yushania alpina* grown at Tikur-Enchini.

	Extractive				Cellulose				Ash			
Age	Top	Middle	Bottom	mean	Top	Middle	Bottom	mean	Top	Middle	Bottom	Mean
3	4.71^{g}	6.65^{e}	6.83d^{e}	6.06^{c}	43.69^{e}	47.14^{bc}	48.24^{ab}	46.36^{a}	2.48^{b}	1.78^{d}	2.63^{ab}	2.3^{b}
4	6.88^{de}	7.25^{d}	8.08^{c}	7.4^{b}	49.53^{a}	46.63^{bcd}	45.11^{de}	47.09^{a}	1.62^{d}	1.29^{e}	2.81^{a}	1.91^{c}
5	5.79^{f}	9.22^{b}	9.95^{a}	8.32^{a}	46.27^{cd}	44.38^{e}	45.34^{de}	45.33^{a}	2.18^{c}	2.45^{b}	2.71^{a}	2.45^{a}
Mean	5.8^{c}	7.7^{b}	8.29^{a}		46.5^{a}	46.05^{a}	46.23^{a}		2.09^{b}	1.84^{c}	2.7^{a}	

***= Significant at $p < 0.001$; ** Significant at $p < 0.01$; *= Significant at $p < 0.05$; ns= Non-significant at p <0.05

obtained by *Razak* [21] in the range of 37.09% - 51.58%. The obtained result was also similar to observation made by *Li* [23], which was found in the range of 43.69% - 49.53%.

Ash Content: The overall mean value of interaction effect of ash content for bamboo age and bamboo culm positions has shown that significantly higher value of ash content, 2.45% was recorded for age 5 bamboo. The minimum mean value of ash content was obtained for age 3 and age 4 bamboo with respective values of 2.3% and 1.97% (Table 4). Comparing the obtained values of ash content with respect to bamboo ages and bamboo culm positions, significantly higher and similar values of ash content were found at bottom culm positions for age 4 and age 5 bamboo, 2.81% and 2.71%, respectively. The least value of ash content was obtained for age 4 bamboo at the middle culm position with value of 1.29%, yielded 54.09% lower than the maximum (Table 4). This value is similar with the previous results reported by *Razak* [21] in the range of 1.28% - 1.89%.

CONCLUSION

It has been found that no significant difference of cellulose content obtained with respect to entire bamboo culm positions (i.e. top, middle and bottom) for the three ages of the selected bamboo (*Yushania alpina*). The amount of alcohol-toluene extractive content increased from the top to the bottom culm position of the bamboo stem and also increased relatively with the bamboo ages. The maximum value of ash content was recorded at the bottom culm position of the bamboo stem comparatively than at the top and middle culm positions for each bamboo ages, whereas the minimum value of lignin content was obtained at the middle culm position for age 4 bamboo.

ACKNOWLEDGEMENT

Authors are grateful and thankful to Wood Technology Research Center (WTRC) of Ethiopian Environment and Forest Research Institute (EEFRI), for its financial and logistics support during the study. Besides, authors would like to thank Laboratory Technicians in Bio-energy and Biochemical Research Division for their valuable and fruitful contributions during the study.

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