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Propagation Techniques for Highland Bamboo (*Arundinaria alpina*) in the Choke Mountain, Northwestern Ethiopia

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Abstract

With the aim of identifying improved propagation techniques that can be applied in a larger scale plantation, six types of vegetative propagation materials obtained from three A. alpina landraces (TIFRO, WELELE and WONDE) were evaluated for their performance under field condition in the Choke Mountain, northwestern Ethiopia. The three techniques namely stump, rhizome and whole-culm had fastest shoot emergence (21-22 days) and superior performance during the four Months period After Establishment (MAE).Shoot height was 262, 233 and 193 cm for stump, rhizome and whole-culm with respective to diameter at breast height of 1.0, 1.1 and 1.5 cm 4 MAE, respectively. The whole-culm method also produced the maximum number of shoots (10 new shoots per propagule), along its stem length (at the upper, middle and butt positions excluding its lower one-third portion) but branch cuttings and culm cuttings had slow shoot emergence (average 30 days) and very poor performance. In general, TIFRO and WELELE landraces had faster shoot emergence (21-23 days) and significantly higher number of new shoots than WONDE landrace. Shoot emergence of the offset (traditional) method was delayed up to the next shooting season (11 MAE) but its performance, including survival rate of the propagules (85%), was superior at that season. New shoots from stump, rhizome and whole-culm were found to be prone (survival rate 17-26%) primarily to strong wind and storm and most probably moisture fluctuations under field condition after four months period hence further research on silvicultural practices that can maximize their persistence is required.

Key words: cuttings, landraces, offset, rhizome-based propagation, Yushania alpina

Introduction

Ethiopia has huge bamboo resource distributed in highland and lowland agroecologies. Old estimates made before 13 years indicated that the country has the largest bamboo cover, about 1 million ha (LUSO, 1997; Ensermu Kelbessa et al, 2000) from two indigenous species *Arundinaria alpina* (highland bamboo) and *Oxytenanthera abyssinica* (lowland bamboo). *O. abyssinica* constitutes about 85% of the whole bamboo cover in the country and is found only under natural stands, whereas *A. alpina* is found both in natural and cultivated forms constituting the remaining share (LUSO, 1997). A study conducted at Hagere Selam (South Nations, Nationalities and Peoples Regional State) and Enjibara (Awi Zone, Amhara) communities indicated that *A. alpina* is an important part of the farming system and serves as a major source of livelihood. Farmers use bamboo resources as their bank account; it provides a ready source of livelihood (UNIDO, 2007).

A. alpina can be used for manufacturing two and three dimensional woven materials, furniture, fencing, food, feed, fuel and many other products through traditional processing. *A. alpina* fulfills ISO standards for industrial products such as ply board, laminated bamboo lumber (LBL), oriented strand board (OSB), medium density fiber board (MDF) and floor boards (EABP, 2008; FRIM, 2008).

Associated with the awareness created by the then East Africa Bamboo Project (EABP) of the Ministry of Agriculture of Ethiopia, from 2006 to 2009, establishing more bamboo plantations for raw material supply for industries, water shade management and income generation at household level has been a big concern of different development actors (discussions with members of the private sector and NGOs). However, shortage of planting materials has become the major problem.

Seeds of *A alpina* are not available on regular basis, besides their low viability (LUSO 1997; Azene Bekele, 2007) and hence are not reliable source of planting material. Under these circumstances, vegetative propagation techniques that can be applied at nursery and field conditions become more important (Lal, et al., 1998; Reddy, 2006). These methods also suit to the requirements of farmers and non-government organizations (NGOs) for their low cost and ease of management (Jiménez and Guevara, 2007).

Different methods of propagation are used for different bamboo species. Rhizome-based techniques such as stump, rhizome and offset are proven techniques for many bamboo species (NMBA, 2004). The whole culm method is the chosen way of vegetative propagation using culm materials (Ronald, 2005) except large culm lengths are difficult to handle. Culm cutting and branch cutting propagation techniques are easy to transport but the absence of initial roots before planting, unlike rhizome-based techniques, makes this method risky (Ronald, 2005). Moreover, performance of a propagation method may depend on its size i.e. on the amount of carbohydrate reserve of the propagule (Berdowski and Siepel, 1988; Li et al., 1998). Accordingly, species that have prominent and stout branches promote satisfactory shoot and root development (Ronald, 2005). A successful method for vegetative propagation must promote the development of roots, rhizome and shoots if propagules are to survive after being planted (van Dorssor and Faulds, 1991; Kumar, 1992; Kumar and Pal, 2003).

Nevertheless, so far, studies aimed at looking for cheap and efficient propagation techniques of *A. alpina* have not come up with a satisfactory method. From a research done in Southern Ethiopia, the offset (traditional method) was found to be superior propagation technique (Tesfaye Hunde et al., 2005). However, this method has shortcomings as (i) the offsets are bulky, heavy and difficult to transport, (ii) the number of offsets that can be extracted from established clumps are limited therefore large scale plantation is not possible, (iii) excavating out and transportation of offsets are labor intensive and expensive, (iv) continued extraction of offsets often cause damage to the parent clumps (Koshy and Gopakumar, 2005).

Thus searching for propagation techniques that are cheaper and more efficient than the traditional method has become one pressing research problem in Ethiopia. In this regard, evaluating the different vegetative propagation techniques is important. Since vegetative propagation might be affected by culm wall thickness of bamboo species or landraces (Banik, 1980), testing the dominant landraces (Yigardu Mulatu and Masresha Fetene, 2011) under Choke Mountain may be of importance. Based on this understanding, this paper tries to address the following objectives under field condition: (1) determine the performance of rhizome-based and cutting propagation techniques in producing new shoots that can grow into seedlings and culms; (2) determine shooting capacity of nodes along stem length of the whole-culm propagation technique (3) investigate the effect of three *A. alpina* landraces in shooting performance of the different propagation techniques under Choke Mountain conditions.

Materials and Methods

Location of the study site

This work was conducted in Gedamawit Zuria Peasant Association of Sinan District in East Gojam Administrative Zone of Amhara National Regional State. The site is located 330 km northwest of Addis Ababa and 30 km to the north of the zonal city, Debre Markos, within the Choke Mountain range. The geographic location is 10°32'14.2'' to 10°34'40'' N; 037° 45' 30.7'' to 037° 46' 06.2'' E. with altitude of 2,954 masl.

Climate during the study period

Mean annual rainfall of the area is 1447 mm (20 years average data collected from RebuGebeya Meteorological Station of the Ethiopian Meteorology Agency). Average temperature is 16°C (extrapolated from nearby stations using LocClime 2.0). The average monthly rainfall and temperature during the study period (2009 and 2010) is presented in Fig. 1. The main rainy season extends from June to September and the high temperature months are from January to April. The main rainy season that extends from June to September is the shooting and recruitment time for bamboo in the area.

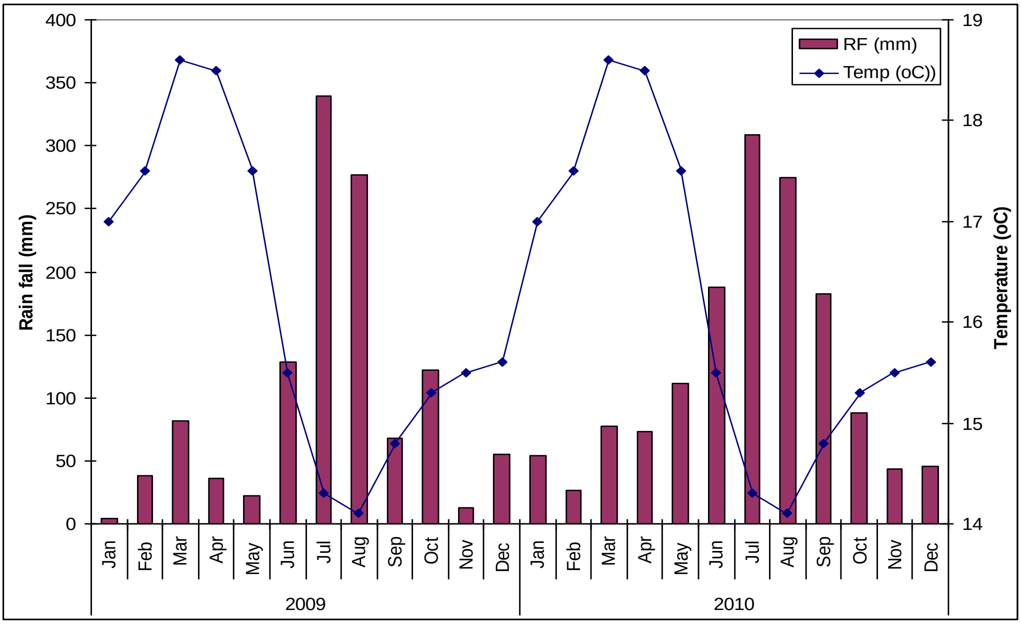

Figure 1: Monthly rainfall and temperature distribution of the study area in 2009 and 2010.

Site selection

The planting site used was a well drained soil on a gently sloping land. It was nearer to bamboo forests and other vegetations that can serve as wind break for established propagules and newly coming shoots. The availability of water source was also taken in to consideration during site selection so that supplemental watering during the dry spells, up to 4 months time, of the experimental period was possible.

Planting bed preparation and soil mix used

The land used for planting was thoroughly cultivated with oxen plough. Plots of varying length (based on the length of the planting material) but a constant (2 m) width were laid out and raised beds were prepared. The size of the planting pit also varied according to the size of the planting material to be tested and prescriptions of manuals. The offsets (farmers' method) were planted in 60-70 cm deep x 60 cm wide x 60 cm long pits. In this method, since the planting material was difficult to plant in upright position, it was planted by tilting to about 25-30^{O}. However the stump and rhizome were fitted in 25-30 cm deep x 60 cm wide x 60 cm long pits, as only the rhizome part should be buried in the pit and no problem of heavy weight to support. The maximum depth of the trench for planting the whole-culm and culm cuttings was 15 cm and its length varied based on the size of the propagules whereas branch cuttings were fitted in 5 cm deep pits. Thin layer of (about 5 cm) compost fortified with local soil was added at the base of propagules while planting in order to make the soil more porous and increase fertility.

Preparation of planting materials

The plating materials (Fig. 2) of this experiment were prepared following manuals for propagation of tropical bamboos by Banik (1995), NMBA (2004) and Ronald (2005). The rhizome used as one treatment in this experiment was prepared by severing the whole rhizome together with the accompanying root system, using a sharp axe, from the parent rhizome. Preparation of the stump (rhizome with culm-stock) was similar to that of the rhizome but in this case the base or lowermost portion of the culm (2-3 nodes) was retained. Offset (rhizome with roots and culm) or the traditional method was prepared by severing the rhizome together will all aboveground plant parts.

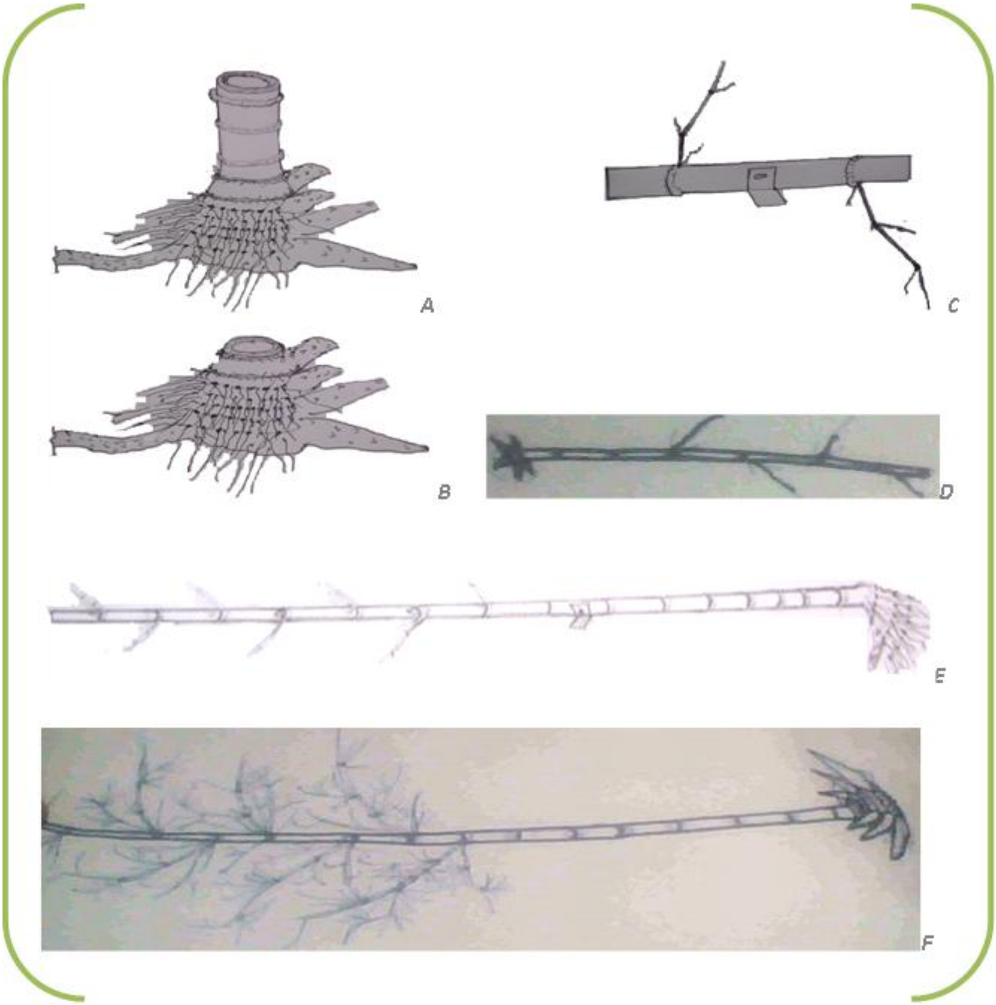

Figure 2: Planting materials used for the study
(A) Stump (Rhizome-offset); (B) Rhizome; (C) Culm cuttings of two nodes; (D) Branch cuttings with five internodes and roots; (E) Whole-culm (all plant parts of the plants except branches and leaves), planting is done horizontally in a furrow; (F) Offset (the farmers' method); all parts of the plant except prunings of the top part after 15 internodes for big propagules. Planting is upright position but with some 20-30^{O} inclination.

The upper most part of the culm was removed, so that bigger portion (12-15 nodes for big culms) and the corresponding branches and leaves were retained. Under the whole-culm method, the culm together with the stump (that keeps moisture and can also produce new sprouts) was severed from the parent rhizome. The top was cut with a slanting cut, leaving 12 to 15 nodes for big culms. All primary branches were pruned to two nodes. The attached rhizome in this method did not have be big like the offset, stump or rhizome methods. For the method of culm cutting, culm segments of 2 nodes bearing healthy branches were used after trimming-off the branchlets to two internodes. The upper most and lower most parts of culms were not included. Primary branches that had aerial roots at the base were used for the branch cutting technique. The branches were trimmed-off to two nodes before planting.Age of mother plants of all the planting materials except branch cuttings were one year. Branch cuttings were severed from 3 to 4 years old plants, as plants of this age harbor branches that developed adventitious aerial roots that was the basis of this technique.

Tending operations after establishment

The trial was established on July 10, 2009 when the soil got sufficiently wet following the start of the main rain season, which is also the time farmer in the area plant bamboo. Supplemental watering was done when there was no rain for more than a day in September and October. A layer of mulch of sorghum straw was applied to plots to retain moisture and protect them from weather extremes. Weeding and hoeing: was done twice in the rainy season of 2009 (August and September) and two times in 2010 rainy season (July and September).

Experimental design and treatments

The experimental design used was Factorial Randomized Complete Block Design (RCBD). There were two factors namelypropagation technique (six levels) and landrace (3 levels) giving a total of 18 treatment combinations. The six propagation techniques used as factors were offset (farmers' practice), stump or rhizome-offset, rhizome, culm cuttings, branch cuttings and whole-culm. The landraces were locally called TIFRO, WELELE and WONDE. Each treatment combination of propagation techniques x landrace was replicated three times. Nine plants were used for each treatment combination.

Data collection

The time of data collection was set to be 2, 4 and 15 months after planting so as to see the performance of the new shoots in the active growing period (2 and 4 months) and to see their persistence after the long dry spell that is followed by the next year's rainy season (at the age of 15 months). Days to shoot emergence was recorded during the first 2 months after establishment. The number of new sprouts was counted, and their height and diameter measured at each data collection period. Because of the difficulty of identifying whether a propaguel is dead or not, and so as avoid disturbance on buried propaguels at 2 and 4 months after planting, survival count of propagaules was made only at the final period of data collection. The diameter (root collar diameter at 2 and 4 months and diameter at breast height at 15 months after planting) and height of the new shoots were measured using diameter caliper and 4 m long graduated ruler, respectively.

Data analysis

Data analysis was made using different functions of PASW (Predictive Analytical Software) Statistics 18. Descriptive statistics was used before the actual analysis to see into the distribution of observations. Normality and homogeneity of variances were checked before the actual analysis. One-Way-ANOVA and two-way-ANOVA was then conducted. Tukey's Honest Significance Difference (HSD) test was used throughout the comparisonwhen statistically significant differences (p<0.05) were observed. Sigma Plot 10 was used to present the analyzed data in different graphs.

Results and Discussion

Days to shoot emergence

Days to shoot emergence for propagules of the different propagation techniques significantly varied (p=0.000) ranging from 21 to 30 days. Mean values of the fastest rates of shoot emergence (21-22 days) were from rhizome, stump and whole-culm (Table 1). Culm cuttings took an average of 26 days to produce new shoots. The longest average time (30 days) taken for shoot emergence at the first shooting season was from branch cuttings (Table 1). Only 2 shoots emerged from offsets after 26 days. Days to shoot emergence also significantly varied (p=0.005) among landraces. Shoot emergence from propagules of landrace WELELE took 21 days, followed by TIFRO (22 days) and WONDE (23 days).

Table 1. Days to shoot emergence after establishment of propagules under different propagation techniques and landraces

Factors	Days to shoot emergence
Propagation technique	
Rhizome	21^{b}
Stump	21^{b}
Offset	-
Whole-culm	22^{b}
Culm cutting	26^{ab}
Branch cutting	30^{a}
Landrace	
WONDE	24^{a}
WELELE	21^{c}
TIFRO	23^{b}

n=9, Tukey HSD (alpha<0.05), (-) indicates that the offset method didn't sprout more than two shoots that can be statistically compared with other propagation techniques.
Mean separation was made after analyzing the arcsine transformed data. Presented are actual values.

Number and size of sprouts

The average number of new shoots sprouted 2 months after establishment (MAE) was 10, 2, 3 and 2 per propagule for the whole culm, stump, rhizome and culm cuttings propagation techniques, respectively. The average number of sprouted shoots 4 MAE followed similar trend to the performance at 2 MAE (Table 2). The average number of new shoots was significantly higher (p=0.000) for the whole-culm technique than other propagation techniques. The rhizome and stump had also significantly higher values than the offset and branch cuttings. The number of new shoots per propagule for offset and branch-cuttings was less than one. Culm cuttings had two new shoots per propagule2 MAE.

Average maximum root collar diameter for the whole culm, rhizome and stump techniques was 3.0, 2.3 and 2.2 cm, respectively (Table 2) 2 MAE. The whole-culm had statistically higher (p=0.000) average maximum diameter followed by rhizome and stump 2 MAE. Average maximum height for rhizome, stump, offset, culm cutting and branch cutting was 47, 42, 5, 16, and 10 cm, respectively. Rhizome and stump had significantly higher (p=0.000) height than offset, culm-cutting and branch-cutting. The whole-culm had height of 27 cm.

The values for number, diameter and height of new shoots 4 MAE followed a similar trend to 2 MAE. But during this assessment time, the rapid shoot elongation of bamboo shoots was clearly seen. The height increased to 262, 233 and 193 cm for stump, rhizome and whole-culm, respectively. Height values of stump, rhizome and whole-culm were significantly higher than offset, branch-cuttings and culm-cuttings 4 MAE. The diameter at breast height (DBH) values of shoots 4 MAE was the highest for whole-culm (1.5 cm) followed by rhizome (1.1 cm) and stump (1.0 cm) (Table 2).

The effect of landraces was statistically different only for height 2 MAE. Average maximum height of TIFRO and WELELE landraces was significantly higher (p=0.000) than WONDE landrace 2 MAE (Table 2). The number of shoots per propagule was statistically different among landraces 4 MAE. TIFRO and WELELE landraces had significantly higher number of new shoots (p=0.042) than WONDE landrace, considering all propagation techniques during the four months study period. But the interaction effect of landrace and propagation techniques was not statistically significant (Table 2). Values on DBH and Average maximum height were not statistically different among landraces 4 MAE.

Table 2: Total number of sprouts per propagule, average maximum DBH and average maximum height of sprouts of rhizome-based propagation techniques 2 MAE

	df	Number of sprouts per propaguel		Average maximum diameter of sprouts (cm)		Average maximum height of sprouts (cm)	
		2	4	2	4	2	4
		Months after establishment					
Propagation technique							
Branch cutting		0.2 ^{cd}	0.09^{c}	_	_	10.43^{b}	26.2^{c}
Culm cutting		1.7 ^{bc}	0.14^{c}	_	_	17.57^{b}	36.9^{c}
Offset		0.04^{d}	0.05^{c}	_	_	5.00 ^{b}	37^{c}
Rhizome		2.5^{b}	2.21^{b}	2.33^{ab}	1.1^{b}	46.57^{a}	233^{ab}
Rhizome offset		1.7^{bc}	1.82^{b}	2.15^{b}	1.03^{b}	41.63^{a}	262^{a}
Whole-culm		10^{a}	5.9^{a}	3.01^{a}	1.53^{a}	27.00^{ab}	193^{b}
Landrace							
WONDE		2.33	1.46^{b}	2.79	1.36	20.14^{b}	185.70
WELELE		2.58	1.90^{a}	2.34	1.16	31.60^{a}	152.90
TIFRO		2.83	1.76^{ab}	2.4	1.05	31.93^{a}	128.70
Corresponding ANOVA							
Propagation technique (PT)	5	**	**	**	**	**	**
Landraces (LR)	2	ns	*	ns	ns	*	ns
PT X LR	10	ns	ns	ns	ns	*	ns
Error	28						

*Significant at 0.05, ** significant at 0.001, ns= non-significant; (-) indicates that the new shoots from branch cutting, culm cutting and offset were less than breast height (1.3 m) diameter 4 MAE hence DBH not measured. Average maximum diameter 2 MAE was measure at the root collar while 4 MAE at 1.3 m above ground.

Performance of the whole-culm propagation technique along height

The average number of new shoots sprouted 2 MAE at the top, middleand butt positions was 8, 2 and 1 per propagule, respectively. The number of shoots per propagule at the top position was significantly higher (p=0.000) than at the middle and butt (Table 3, Fig. 3) 2 MAE. The lower one-third of the culm position had no shoot sprouts hence no data for all the variables. WELELE landrace had significantly higher (p=0.05) number of new shoots than other landraces.

Average root collar diameter of new shoots sprouted 2 MAE at the top, middle and butt positions was 1.3, 2.7 and 3.2 cm, respectively. Root collar diameter was significantly higher (p=0.05) for the butt followed by middel and top. Average maximum height of new shoots sprouted 2 MAE at the top, middle and butt positions was 36.8, 28.7 and 36.9 cm, respectively. Average maximum height of new shoots was not statistically significant 2 MAE.

Similar trend was observed in the data collected 4 MAE, but this time the values were generally lower. But during this assessment, the rapid shoot elongation of bamboo shoots was clearly observed. The height increased to 215, 88 and 147 cm for the butt, middle and top positions, respectively. The values at the butt, middle and top positions were significantly different (p=0.000) (Table 3). Although, for all measured variables significant difference among all landraces 4 MAE was not observed, WELELE and TIFRO exhibited increasing trend for number and height of shoots.

Table 3: Number of shoots per propagule, average maximum root collar diameter and average maximum height of new shoots at different positions of the whole-culm method two and four months after establishment.

Factor	df	Number of new shoots per propagule		Average maximum diameter (cm)		Average maximum height (cm)	
		2	4	2	4	2	4
		Months after establishment					
Position							
Butt		0.8[c]	1.04[b]	3.2[a]	1.43	36.9	215[a]
Lower		-	-	-	-	-	-
Middle		2.4[b]	1.42[b]	2.7[ab]	0.4	28.7	88[b]
Top		7.5[a]	3.54[a]	1.3[b]	0.6	36.8	147[ab]
Landrace							
WONDE		2.2[b]	1.5	3.0	1.0	30.2	132
WELELE		2.6[ab]	2.03	2.3	1.1	37.5	169
TIFRO		3.2[a]	2.31	2.45	1.3	38.5	150
Corresponding ANOVA							
Position	2	**	**	*	ns	ns	**
Landrace (LR)	2	*	ns	ns	ns	ns	ns
LR X Position	4	ns	ns	ns	ns	ns	ns
Error	9						
Total	20						

*Significant at 0.05, ** significant at 0.001, ns= non-significant, (-) indicates that the lower position of the whole-culm had no new shoots sprouted. Average maximum diameter 2 MAE was measure at the root collar while 4 MAE at 1.3 m aboveground. (n=9 for position and 12 for landrace; p<0.05; Tukey HSD)

Figure 3: New sprouts (shoot and root) from three positions of the culm and at its butt of TIFRO landrace 15 months after establishment (upper layer); new sprouts of the top position magnified (bottom layer).

Number and size of new shoots 15 months after establishment

The number of shoots per propagule was 4, 2, 2 and 1 for the whole-culm, stump, offset and rhizome techniques, respectively, 15 MAE. The value for the whole-culmwas significantly higher (p=0.01) than the rhizome method but not with stump, offset and rhizome technique (Table 4). Diameter at breast height of the new shoots was highest (p=0.01) for the offset (1.9 cm) and whole-culm (1.4 cm) methods followed by rhizome (1.1 cm) and stump (1.0 cm) methods (Fig. 4). Survival rate of the offset method (85%) was significantly higher (p=0.000) than whole-culm (26%), rhizome (20%) and stump (17%) methods. Branch cuttings and culm cuttings did not survive up to 15 MAE hence there is no data presented for the parameters. The effect of landraces was not significant for number of new shoots, DBH and height.

Table 4: Survival percent and number of shoots per propagule and average maximum diameter of new shoots of vegetative propagation techniques 15 months after establishment

	df	Number of shoot Per plant	Average maximum DBH (cm)	Average maximum height (cm)	Survival rate (%)
Propagation technique					
Rhizome		1.3^{b}	1.1^{b}	196^{ab}	20^{bc}
Stump		1.6^{ab}	1.0^{b}	170^{ab}	17^{bc}
Offset		1.9^{ab}	1.8^{a}	267^{a}	85^{a}
Whole-culm		3.5^{a}	1.4^{ab}	146^{b}	26^{b}
Landraces					
WONDE		1.4	1.6	220	23
WELELE		2.4	1.2	187	27
TIFRO		2.6	1.4	181	23
Corresponding ANOVA					
Propagation technique (PT)	3	**	*	*	**
Landrace (LR)	2	ns	ns	ns	ns
PT X LR	5	ns	ns	ns	ns
Error	13				

*Significant at 0.05, ** significant at 0.001, ns= non-significant; (n=18 for landraces and 9 for propagation techniques; p<0.05, Tukey HSD)\

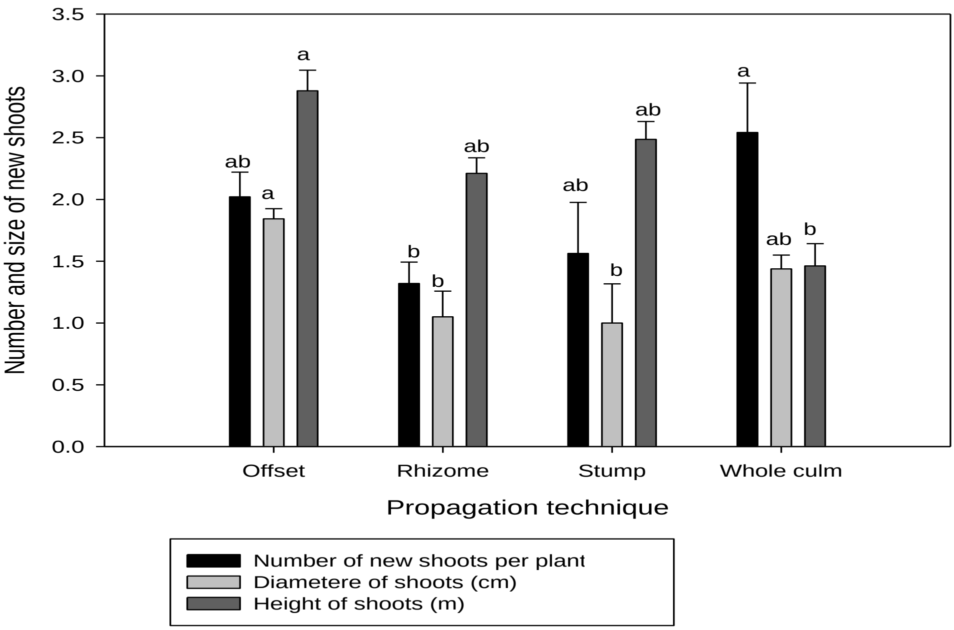

Figure 4: Number of shoots and their size of four propagation techniques 15 months after establishment

Conclusion and Recommendation

The number and size of new shoots from rhizome and stump techniques was the highest during the four months period but they become challenged by prevailing strong wind and storm and probably also moisture fluctuations during October and later months. Hence the persistence of newly produced shoots was reduced and mortality increased 15 MAE. These methods managed to produce new roots however their performance as compared to the offset (traditional) method was generally in reversed manner across the two shooting seasons. Planting depth and level of compaction could bring about differences in shooting time of rhizome based techniques and the offset method. Therefore, further research on planting depth, other than that used in this study and general silvicultural practices is recommended so as to increase the persistence of new shoots against wind damage and moisture conservation.

Culm cuttings and branch cuttings produce shoots in one month period but there was no root development hence propagation of *A. alpina* by these methods becomes uncertain. The whole-culm propagation technique produced high number of shoots with reasonable size at the butt, middle and top positions. There was a remarkable rhizome production of the rooted shoots when this technique was used. This method can be used to get starting materials for macro-propagation purposes so that mass propagation of seedlings is possible under nursery conditions. However, seedling production using this technique requires adoption of better nursery practices.

Considering the good performance of big size planting materials, rhizome-based and whole-culm techniques in this study, the poor performance of small sized planting materials (culm cuttings and branch cuttings) appears to be related to the lower amount of food reserve.

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