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Field Performance of Tagasaste (*Chamaecytisus palmensis*) Under Different Harvesting Management in a Tropical Highland Area of Ethiopia

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Abstract

*Tagasaste (**Chamaecytisus palmensis**) is one of productive multipurpose tree species grown in the tropical highlands of Ethiopia. Despite its potential role as a source of forage and natural resource conservation, adequate studies were not made on agronomic practices such as establishment, harvesting managements and utilization. The objectives of this study were to investigate the effect of establishment and subsequent harvesting managements on biomass (BM) yield, crude protein (CP) content, botanical fractions of total biomass and persistency of tagasaste. Establishment of tagasaste was undertaken for three consecutive years at Holeta Research Center (HRC) in the highlands of Ethiopia. The two harvesting management trials, harvesting stage and growing season were arranged separately in a randomized complete block design with three replications. In harvesting stage study, four treatments of harvesting stage including HS1 (3 harvests per year at 4 months interval), HS2 (2 harvests per year at 6 months interval), HS3 (one harvest at 8 months and the 2^nd^ harvest after 4 months) and HS4 (one harvest at 10 months and the 2^nd^ harvest after 2 months) were compared annually. In the growing season study, tagasaste was allowed to regrow for 6 months so that exposed to the main rain, dry and short rainy seasons of the area. Planting and harvesting year had a significant ($P<0.01$) effect on BM yield during establishment and subsequent years. Mean annual dry BM yield was 7.3, 9.5 and 11.3 t ha^{-1}, out of which about 55% was edible forage during the establishment, second and third year, respectively. Tagasaste produced 7.7, 11.8, 9.9 and 12.2 t ha^{-1} dry BM and 0.72, 0.97, 0.83 and 1.12 t ha^{-1} CP from edible forage when harvested at HS1, HS2, HS3 and HS4, respectively. Tagasaste regrowth during the main rainy season, dry season and short rainy season produced 6.7, 1.7 and 5.8 t ha^{-1} dry BM per 6 months, respectively. From this study it is concluded that harvesting management could substantially improve performance and annual yield of tagasaste. Harvesting either at HS2 or HS4 improved BM, edible forage and CP yields of tagasaste. Therefore, these agronomic management practices has vital role to increase the productivity of tagasate in the central highlands of Ethiopia.*

Keywords: tagasaste, harvesting management, season, biomass, crude protein, tropical highlands

Introduction

Nutrition has been documented to be one of the most important factors limiting livestock production in the traditional smallholder sector of Ethiopia, despite a massive increase in demand for food of animal origin (Berhanu *et al.*, 2002). This is because livestock feeds in the smallholder sector largely depend for a greater part of the year on natural pastures and crop residues which are usually fibrous and devoid of most essential nutrients including proteins, energy, minerals and vitamins which are required for increased rumen microbial fermentation and improved performance of the host animal. Inadequate nutrition in animals has often been associated with heavy economic losses to the farmers. In order to improve the productive and reproductive capacity of smallholder livestock, there is a need to look at ways of extending the availability and quality of feedstuffs produced on smallholder farms. One potential way for increasing the quality and availability of feeds for smallholder ruminant animals in the dry season may be through the use of fodder trees and shrub legumes.

Tagasaste (*Chamaecytisus palmensis*) is an introduced and adapted multipurpose fodder tree originated in the Canary Islands (Snook, 1986). Since its introduction its adaptability and potential biomass productivity has been assessed in many highland areas of Ethiopia (Holetta, Kulumsa, Adet, Sinana etc.). High biomass yield and quality even during dry season, roles in soil conservation and fertility improvement favour its fast adoption and use by smallholder farmers in cool highlands of Ethiopia (Assefa 1998b). Despite the adoption of tagasaste by smallholder farmers in Ethiopia, studies made on different agronomic practices such as plant spacing, harvesting stages, cutting heights, growing seasons etc., and feeding strategies to livestock are scanty. However, knowledge on improved agronomic practices including establishment methods, planting densities, fertilizer rates, harvesting stages and seasons, Rhizobium inoculation, grazing systems, weeding practices, alley cropping, etc. are important management aspects that showed tremendous impact on forage yield, quality, persistency and environmental protection of forage crops (Gault et al., 1994; McGowan and Mathews, 1994; Berhe and Tothill, 1997; Assefa, 1998a; Wiley, 2000b; Seymour, 2001). The objective of this study was therefore to evaluate the establishment and effect of harvesting management (stage of harvest) and growing season on the biomass productivity, proportion of the different plant parts, crude protein (CP) yield and persistency of tagasaste in the cool tropical highland conditions.

Materials and Methods

Description of Experimental Site

The experiment was conducted at Holetta Research Centre in the highlands of Ethiopia. The center is situated at an altitude of 2400 m. asl., latitude of 9^{O} N, and longitude of 38^{O} 30' E. The area has a bimodal rainfall where about 75% (700 mm) falls during the main rainy season from July to September and about 25% (230 mm) falls during the short rainy season from February to June. Aaverage maximum and minimum temperature of the area is 22 °C and 0.2 °C respectively. From November to January, the minimum temperature drops sometimes below zero and frost occurs occasionally (HRC, 2003). The annual rainfall distribution, the average maximum and minimum air temperature of the site during the trial period are given in Figure 1 and 2, respectively. The soil of the testing site is clayey, drained red soil (Nitosols) having a texture of 65% clay, 21% silt and 14% sand, a pH of 5.7, and contain 11.4 mg kg^{-1} phosphorus, 1.9 g kg^{-1} nitrogen, 17.1 g kg^{-1} potassium, and 13 g kg^{-1} organic carbon.

Establishment

Boiling water treated tagasaste seeds of variety *MOA*, which is dominantly grown by smallholder farmers in the highlands of Ethiopia were raised to seedlings in polyethylene plastic pots in a nursery during the dry season (3 months old). Transplanting to ploughed fields was made at the beginning of the main rainy season (early July). Seedlings were planted in rows spaced one meter apart with 0.5 m spacing between plants. Spot application of fertilizer (100 kg ha^{-1} diammonium phosphate) was made once at the time of transplanting seedlings for better root development. Tagasaste was established for three consecutive years during 2002, 2003, and 2004. Evaluation of harvesting management studies were made on regrowths for each of the established tagasaste plantations.

Harvesting Management and Experimental Design

Two harvesting management studies, namely, harvesting stage where tagasaste regrowths harvested at different length of growing period, and growing season in which tagasaste was grown for equal length of six months in the different seasons were carried out. In the harvesting stage study, four treatments of harvesting namely HS1 (3 harvests per year at 4 months stage), HS2 (2 harvests per year at 6 months stage), HS3 (one harvest at 8 month and a 2nd harvest after 4 months), and HS4 (one harvest of 10 months and a 2nd harvest after 2 months) were compared. All plots were pruned every year in June and harvesting managements were made according to the treatments from this onward. BM and CP yields were compared on an annual basis. The treatments were laid out in a randomized complete block design in three replications with a plot size of 6 m x 10 m (120 plants).

In the growing season study, tagasaste was allowed to regrow for 6 months during the 3 major seasons of the area, namely the main rainy season (July – December), the dry season (October to March) and the short rainy season (February to July). The growing season treatments were laid out in a randomized complete block design in 3 replications with plot size of 5 m x 10 m (100 Plants).

Harvesting and Sample Processing

In both the harvesting stage and growing season experiments, tagasaste was harvested manually. The whole aerial part 50 cm above the ground was harvested and total BM was measured excluding the guard rows. A BM sample of 5 to 8 kg was taken and fractionated into growing buds, leaf, edible branch (<3 mm diameter), bark and stem. Samples of the biomass and fractionated plant parts were dried in a forced air draft oven at 60°C to constant weights for dry matter (DM) determination. The CP contents of the different plant parts were analysed according to the procedures of AOAC (1990).

Data collection and statistical analysis

Data on harvesting stages and growing season were compared using analysis of variance. Combined analysis of data over planting and harvesting years was done using the general linear models of SAS and means comparisons was made by Tukey's studentized range test (SAS, 2001). The general model $Y_{ijkl} = \mu + h_i + t_j + b_k + p_l + (h*t)_{ij} + e_{ijkl}$, where Y is the measured response, μ = over all mean, h_i = the effect of the i^{th} harvesting year, t_j = the effect of the j^{th} treatment (harvesting management as stage or season), b_k = the effect of the k^{th} block, p_l = the effect of the l^{th} plant part, $(h*t)_{ij}$ = the year and treatment interaction and e_{ijk} = the error term was used for analysis of the collected data.

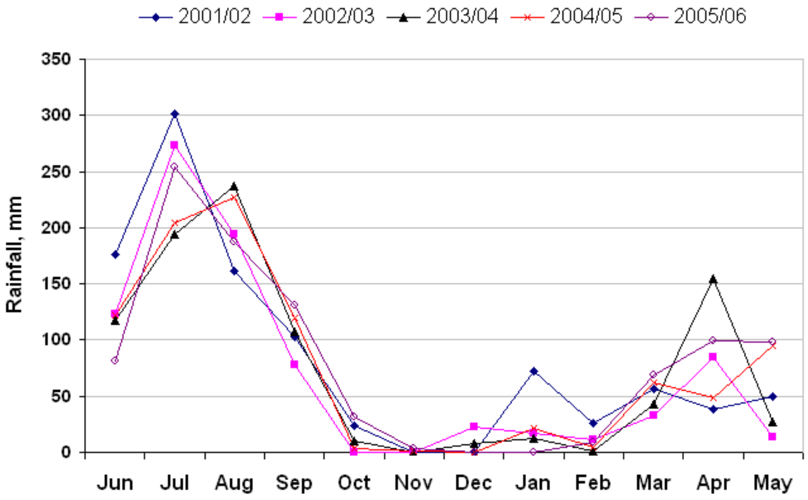

Figure 1. Monthly total rainfall (mm) distribution at the experimental site (Holetta) during the experimental period

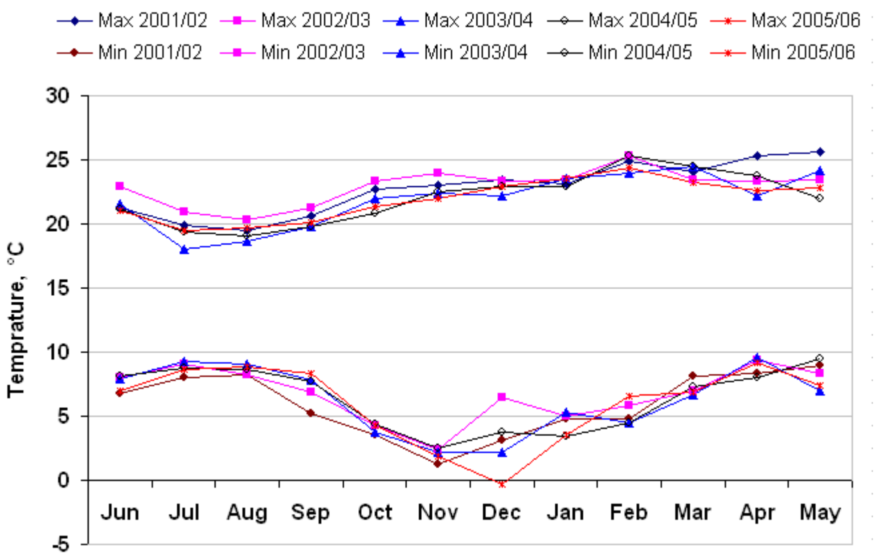

Figure 2. Mean maximum and minimum air temperature (°C) at the experimental site (Holetta) during the experimental period

Results and Discussion

Establishment

In all planting years, tagasaste trees were established through transplanting seedlings raised in nursery for about four months. The effect of planting year on establishment (survival rate), plant height and BM yield, at an age of one year is given in Table 1. The results showed that, there were significant differences ($P<0.01$) in survival rate, plant height and biomass yield among the planting years. Seedling survival rate was higher ($p<0.01$) during the first and second compared to the third planting year.

Ease of establishment was found to be one of the major limitations to widespread adoption of some browse trees (Brandon and Shelton, 1997). The difference observed among the planting years may be due to fluctuations in monthly and seasonal climate variables (rainfall and temperature, Figure 1, pest and insect attack, weed competition and soil fertility (Brandon and Shelton, 1997 and Wiley, 2000b). Although some reports (Lazier, 1987) indicated that tagasaste can be propagated by cutting or direct seeding, transplanting seedlings, under the Ethiopian highland conditions was found to be effective. Weed competition and low germination due to hard seed coat limit the success of direct seeding, while cutting was virtually unsuccessful (HRC, 1992). If direct planting is required, seed treatment through soaking in boiling water for 7-9 minutes is necessary to increase the germination rate from 2-3% to 71% and contributes to better establishment and save extra seed that must be used for compensating for low germination (Assefa, 1998a). In this study, an average survival rate of 80.2% was achieved although higher survival rate (93%) was also reported by Berhe and Tothill (1997). The lower survival rate observed at Holeta may be attributed to wet and cold weather at transplanting, low moisture stress during dry season and occasional frost occurrence in periods from October to January (Figure 2). The lowest survival rate (75.2%) was due to sever frost during 2004 planting year.

Seedlings were harvested at the beginning of the main rainy season in the following year at the age of one year. The highest plant height (214.2 cm) and the lowest dry BM were recorded from 2004 plantation (Table 1). The lower BM yield was owing to the influence of sever frost which significantly (P<0.01) reduced the survival rate and/or need of longer period for recovery of survived seedlings. In all the planting years tagasaste had a high proportion of edible matter (leaves and branches) with a range of 64 to 68%. The higher edible matter proportion of total biomass produced was related to vegetative growth that favoured sink accumulation in actively growing leaves, buds and young branches. In all the planting years, the average proportion of plants bearing flower were only 1% (Table 1). The study also revealed that, harvesting or mechanical pruning at an age of one year did not affect the persistence of the seedlings.

Regrowth Plant Height, Biomass and Crude Protein Yield

Regrowth performance of tagasaste under different harvesting stages during the second year is shown in Table 2. The effects of the harvesting years on plant height, BM and CP yields during the second year regrowth were significant (P<0.01). The performance of tagasaste in the establishment year had no apparent effect on the BM productivity of tagasaste in the second year. The poorly established plots in the year 2004 (Table 1), performed better than others during the second year. Increased BM yield with decreasing plants per unit area is attributed to better access and reduced competition for moisture and nutrients (McGowan and Mathew, 1994). The average BM yield increased was 30% during the second year compared to the establishment year. The increased BM yield was mainly due to the induction of several lateral shoots following mechanical pruning of the trees at an age of one year. Wiley (2000c) also reported that mechanical pruning or very light grazing at early stage enhance production of lateral shoots and hence better BM yield. However, plant height did not show much variation.

As indicated in Table 2, BM yield, plant height and CP yield were significantly (P<0.01) affected by harvesting stage. At 4 months harvesting stage (HS1), 3 harvests are expected annually but in all the three years, the second harvest was either extremely low or no harvestable BM yield was obtained, which practically limit to only two harvests. In both first and second harvests, significant differences were observed in BM yield and plant height (P<0.01).

Table 1. Performance of tagasaste in the first year of establishment

Measured parameters	Planting year 2002	2003	2004	Mean
Survival rate of seedlings (%)	83.8[a]	81.6[a]	75.2[b]	80.2
Plant height (cm)	167.3[c]	193.6[b]	214.2[a]	191.7
Average biomass yield (t/ha/year DM)	7.54[b]	8.23[a]	6.04[c]	7.27
Proportion of botanical fractions (g/kg DM biomass)				
Leaf	457	416	385	419
Branch	208	222	294	241
Stem	335	362	321	339
No of plants started flowering (%)	0.8	1.2	0.9	1.0

Means within a row with different letters are significantly different

In the first harvest, the highest (P<0.01) mean BM yields of 9.91 t ha^{-1} was obtained from HS4 (harvest at 10 and 2 months later) followed by HS2, HS3 and HS1 in a decreasing order. The results show that the differences in BM yield obtained from HS2, HS3 and HS1 in the first harvest was not significant indicating lack of reasonable dry matter accumulations due to extended growing period in dry and short rain seasons. Cumulative effects of morning frost, higher day time temperature (evapotranspiration) in periods between October and January and lack or lower rainfall extending up to March decreased physiological activities of the plants (Gonzalez-Rodrigues et al., 2005). However, harvest from extended growth period under HS4 gave higher BM yield which was mainly due to absence of disturbance during critical stress periods. Probably, this contributed to efficient utilization of residual and short rain moistures and fast recovery favouring high BM accumulation.

In several studies (Seymour, 2001; Latt et al., 2000; Avice et al., 1997; Douglas et al., 1996 and McGowan and Mathews 1992) it has been shown that frequent harvesting negatively affect nutrient reserve and water use efficiency of trees resulting to low BM yield. Depending on seasonal climatic conditions two to three harvests per year were found to give optimum BM yield, which is in agreement with this finding that longer regrowth periods (HS2 and HS4) during first harvest were found to give high annual BM production under Ethiopian highland condition.

Harvesting stages in the first harvest seems to have an effect on the second harvest where HS2 gave the larger (P<0.01) BM yield. This may be attributed to the adequate length of growing periods and best match to the favourable weather conditions of the year, which helps plants in improving nutrient reserve for fast recovery and high BM production (Avice et al., 1997). The total annual BM yield and the mean BM obtained were in the order of HS2>HS4>HS3>HS1. The differences in mean annual BM yields obtained within treatment groups HS2, HS4, HS3 and HS2 and HS3 were not significant (Table 2). However, mean annual BM yield obtained with HS2 and HS4 was significantly higher than HS1. Higher crude protein yield was obtained either from treatment groups under HS2 or HS4 although Buxton (1996) reported that maturity reduces the crude protein content of forages crops. However, better plant performance at these harvesting stages might have increased atmospheric nitrogen fixation (potential up to 390 kg ha^{-1} yr^{-1}, Unkovich et al., 2000) and improved nitrogen availability for better CP yield. The significant interaction between year and harvesting stages and their effect on BM yield, plant height and CP yield was the reflection of inconsistencies in seasonal rainfall distribution and temperature patterns over years.

Biomass yield, plant height and CP were significantly affected by harvesting stage at third year (Table 3). The mean BM yield was higher by 55% and 19% over establishment and second year respectively. This indicates that successive increase of plant productivity during these periods needs further investigation up to when this trend will continues and start falling. Continued BM yield over the study periods was attributed to increased growing points (shoots) from pruned stem and development of deep root system which improve water and nutrient use efficiency (Aronson et al., 2002; Lefory et al., 2001a & b). The effect of harvesting stage on plant height, BM and CP yields followed the same trend observed in second year, where plant height and BM yield were increased with prolonged harvesting stage. Like the second year, significantly higher ($P<0.01$) BM yield was obtained from HS2 at second harvest. Similarly, the average annual BM and CP yield from the edible fractions were significantly higher for HS2 and HS4.

Table 2. Plant height (cm), biomass (BM) and crude protein (CP) yield of tagasaste harvested at different stages and years the second year regrowth

			First harvest*		Second harvest*		Annual	
Planting Year	Regrowth Harvesting Year	Treatment[1]	Height (cm)	BM (t DM/ha)	Height (cm)	BM (t DM/ha)	BM (t DM/ha)	CP[2] (t DM/ha)
2002	2004	HS 1	170[c]	3.97[c]	201[a]	7.89[a]	11.85[b]	1.10[a]
		HS 2	189[b]	5.50[b]	197[a]	8.07[a]	13.57[a]	1.11[a]
		HS 3	183[b]	5.40[b]	163[b]	4.06[b]	9.46[c]	0.79[b]
		HS 4	227[a]	10.59[a]	97[c]	0.78[c]	11.37[b]	1.05[a]
2003	2005	HS 1	160[bc]	2.56[c]	129[b]	1.56[b]	4.12[b]	0.38[b]
		HS 2	157[c]	3.92[b]	146[a]	3.64[a]	7.56[a]	0.62[ba]
		HS 3	169[b]	5.00[b]	124[b]	1.42[b]	6.42[a]	0.54[ba]
		HS 4	193[a]	7.98[a]	85[c]	0.27[c]	7.98[a]	0.76[a]
2004	2006	HS 1	201[b]	6.07[b]	121[b]	0.71[b]	6.78[b]	0.63[c]
		HS 2	198[b]	7.84[b]	172[a]	4.18[a]	12.02[a]	0.99[ba]
		HS 3	199[b]	6.60[b]	175[a]	3.75[a]	10.35[a]	0.87[b]
		HS 4	243[a]	11.15[a]	110[b]	0.87[b]	12.02[a]	1.11[a]
	Mean	HS 1	177[b]	4.20[b]	150[b]	3.38[b]	7.58[b]	0.70[b]
		HS 2	181[b]	5.76[b]	172[a]	5.29[a]	11.05[a]	0.91[a]
		HS 3	183[b]	5.67[b]	154[ba]	3.08[b]	8.75[ab]	0.73[b]
		HS 4	221[a]	9.91[a]	97[c]	0.64[c]	10.55[a]	0.97[a]
	Effect of year		***	**	***	***	***	***

Means within a column and a year with different letters are significantly different, * P<0.05, ** P<0.01 and *** P<0.001

[1] HS 1 (3 harvests per year at 4 moths stage), HS 2 (2 harvests per year at 6 months stage), HS 3 (one harvest at 8 month and a 2nd harvest after 4 months) and HS 4 (one harvest of 10 months and a 2nd harvest after 2 months).

[2]CP- calculated only from the edible plant parts based on their proportion from the BM yield and CP content.

* First harvest covers durations at which the plots were subjected to their respective treatments (harvesting stages) each year while second harvest was made to clear all the plots once at the beginning of the main rainy season (end of June) to prepare for subsequent year treatments response evaluation.

Table 3. Total biomass (BM), crude protein (CP) yield and plant height of tagasaste harvested at different stages and years during the third year of harvesting regrowths

			First harvest*		Second harvest*		Annual	
Planting Year	Regrowth Harvesting Year	Treatment[1]	Heigh (cm)	BM (t DM/ha)	Heigh (cm)	BM (t DM/ha)	BM (t DM/ha)	CP[2] (t DM/ha)
2002	2005	HS 1	165^{c}	3.73^{b}	184^{b}	5.44^{b}	9.17^{b}	0.85
		HS 2	189^{b}	5.35^{b}	199^{a}	7.29^{a}	12.64^{a}	1.04
		HS 3	179^{cb}	4.69^{b}	162^{c}	3.94^{c}	8.63^{b}	0.72
		HS 4	218^{a}	9.56^{a}	90^{d}	0.79^{d}	10.37^{ba}	0.95
2003	2006	HS 1	212^{c}	5.74^{c}	119^{b}	0.83^{b}	6.57^{c}	0.61^{c}
		HS 2	206^{c}	8.38^{b}	171^{a}	3.99^{a}	12.37^{b}	1.01^{b}
		HS 3	226^{b}	9.92^{b}	165^{a}	3.49^{a}	13.41^{b}	1.12^{ba}
		HS 4	282^{a}	15.98^{a}	106^{c}	0.34^{b}	16.32^{a}	1.49^{a}
	Mean	HS 1	189^{b}	4.74^{b}	152^{b}	3.14^{b}	7.87^{b}	0.73^{b}
		HS 2	198^{b}	6.87^{b}	185^{a}	5.64^{a}	12.51^{a}	1.03^{ba}
		HS 3	202^{b}	7.31^{b}	164^{ba}	3.72^{b}	11.03^{ba}	0.92^{ba}
		HS 4	250^{a}	13.20^{a}	98^{c}	0.57^{c}	13.76^{a}	1.27^{a}
	Effect of year		***	***	**	***	NS	NS

Means within a column and a year with different letters are significantly different, * P<0.05, ** P<0.01 and *** P<0.001, NS- non significant

[1] HS 1 (3 harvests per year at 4 moths stage), HS 2 (2 harvests per year at 6 months stage), HS 3 (one harvest at 8 month and a 2nd harvest after 4 months) and HS 4 (one harvest of 10 months and a 2nd harvest after 2 months).

[2]CP- calculated only from the edible plant parts based on their proportion from the BM yield and CP content.

* First harvest covers durations at which the plots were subjected to their respective treatments (harvesting stages) each year while second harvest was made to clear all the plots once at the beginning of the main rainy season (end of June) to prepare for subsequent year treatments response evaluation.

The effect of growing season on plant height and BM yield of tagasaste harvested at 6 months of regrowth during main rain, dry and short rains in three consecutive production years is indicated in Table 4. Both BM yield and plant height were significantly (P<0.01) affected by the year of harvest and growing seasons. BM yield was significantly higher (P<0.001) when tagasaste regrowth was harvested during the main rainy season followed by short rains with the exception in harvesting year of 2005. In 2005, BM yield was higher during the short rainy season compared to the main rainy season. In all years BM yield and plant height were very low during the dry season.

Table 4. Effect of growing season and harvesting year on the plant height (cm) and biomass (BM) productivity (t ha^{-1} 6 $months^{-1}$) of tagasaste

Regrowth	Harvesting year	Growing season[1] Main rainy season	Dry season	Short rainy season	SEM
Plant height (cm)	2004	184[a]	99[b]	204[a]	16.4
	2005	164[b]	142[c]	174[a]	5.1
	2006	214[a]	118[c]	177[b]	14.5
	Effect of year	***	***	***	
BM (DM t/ha/6 months)	2004	7.85[a]	1.20[c]	6.67[b]	1.04
	2005	4.59[a]	2.57[b]	5.40[a]	0.46
	2006	7.80[a]	1.34[c]	5.37[b]	0.96
	Effect of year	***	***	***	

Means within a row with different superscripts are significantly different
- * P<0.05, ** P<0.01 and *** P<0.001
[1]Six months regrowing period of tagasaste during the 3 major seasons of the area

The interaction effect of harvesting year and growing season on plant height and BM yield was significant (P<0.001). Better moisture availability and temperature lead to higher plant performance and biomass yield during main and short rains compared to dry season. Reduced BM production against high temperature and low moisture level during dry season may be the mechanism by which the trees survive under drought conditions (Buxton, 1996 and Gonzalez-Rodriguez et al., 2005).

Proportion of Plant Fractions

Harvesting year significantly (P<0.01) affected all the plant fractions except the proportion of branch during main rain and short rainy seasons and bark during short rainy season (Table 5). The proportions of botanical fractions over the different growing seasons were also significantly different, with the exception of branch and buds in the years 2005 and 2006 respectively. Conversely, the lower BM yield obtained during the dry season in this study (Table 6) was characterized by high proportion of edible fractions and low proportion of bark and stem.

During the main and short rainy seasons the total actual edible matter was high, however, the proportion of bark and stem was higher in the main rainy season compared to the dry season. The dynamism in proportion of plant fractions at different seasons was as a function of temperature and moisture status, which is in agreement with Buxton (1996) and Gonzalez-Rodriguez et al. (2005) findings. In a study on harvesting stage on leaf to stem ratio, Assefa (1998a) reported that frequent harvesting (4-6 $year^{-1}$) increased leaf proportion up to 71% despite low BM yield.

Table 5. Effect of growing season and year on proportion of different plant fractions (g kg^{-1} DM biomass) in tagasaste

Harvesting Year	Growing Season[1]	Plant part				
		Bud	Leaf	Branch	Bark	Stem
2004	Main rainy season	58.7[b]	313.2[b]	276.0[ba]	80.3[a]	271.8[a]
	Dry season	118.0[a]	392.2[a]	330.4[a]	11.4[b]	147.7[b]
	Short rainy season	53.4[b]	327.2[b]	239.8[b]	76.6[a]	303.1[a]
	SEM	11.1	14.2	16.6	11.5	25.2
2005	Main rainy season	25.0[b]	252.3[b]	222.7	104.0[a]	396.0[a]
	Dry season	71.7[a]	391.3[a]	240.7	72.7[b]	224.3[b]
	Short rainy season	36.7[b]	247.0[b]	205.7	100.7[a]	410.7[a]
	SEM	7.3	24.7	10.4	5.5	30.3
2006	Main rainy season	21.3	243.7[b]	247.3[b]	85.7[ba]	401.7[a]
	Dry season	59.3	319.3[a]	313.7[a]	112.3[a]	195.7[b]
	Short rainy season	41.6	324.1[a]	208.7[c]	69.2[b]	356.3[a]
	SEM	7.1	15.7	16.0	8.0	33.4
Effect of year	Main rainy season	***	**	NS	*	**
	Dry season	***	*	*	***	***
	Short rainy season	***	*	NS	NS	***

Means within a column and within the harvesting year with different letters are significantly different
* P<0.05, ** P<0.01 and *** P<0.001, NS – Non significant
[1]Six months regrowing period of tagasaste during the 3 major seasons of the area

Proportions of dry matter in different plant fractions and crude protein contents of tagasaste forage harvested at different regrowth stages are given in Table 6. Harvesting stage had significant (P<0.01) effect on dry matter proportions of all plant fractions in both first and second harvests. In the first harvest, higher growing bud and leaf proportions were recorded from HS1 and HS4 harvesting stages while the proportion of branch was higher at HS2 and HS3. The proportion of stem in harvest one was higher at HS4 and HS2. However the proportion of bark seems to decrease with increasing growing period. In the second harvest, increased growing period (HS4) favoured higher proportions of growing buds, leaf and branch while higher bark and stem proportions were obtained at HS2. The proportion of the plant parts were on average 4, 27, 22, 10 and 38% for growing bud, leaf, edible branch, bark and stem respectively in the first harvest while 8, 41, 24, 6 and 21% was obtained in the second harvest.

The results indicate that the first harvests was characterized by lower leaf and higher bark and stem proportions, while the second harvest was higher in leaf and lower in bark and stem proportions. The CP level in leaf and growing buds was higher, but lower in the edible branches (Table 6). Harvesting stage significantly (P<0.01) affected the CP content of the growing buds during the first harvest and that of the leaves in the second harvest. Likewise, the proportions of different plant fractions; their dry matter was also varied in response to change in temperature and moisture status during distinct seasons of the area (Buxton, 1996 and Gonzalez-Rodriguez et al., 2005).

Pest and Diseases

Pests are very important at early nursery stage (germination to 2 leaf stage) where the seedlings were heavily damaged by insects, mainly crickets and grasshopper. Other insects such as redlegged earth mite, aphids, bugs, cutworms, cockchafer grubs etc. are reported to attack tagasaste seedlings (Wiely, 2000b). However, this problem did not prolong to the later stage of seedling growth (after 2 leaf stage). Wiley (2002b) reported that, in Australia insect pests are very serious at early seedling stage (2 months), while their attacks decrease with age and become very low at an age of one year. At times of serious insect attack, use of chemical spray can be used to control the problem. Moreover, sowing/planting date is important practice to reduce attacks from insects.

Table 6. Proportions of the biomass to different plant fractions and crude protein contents of tagasaste forage harvested at different regrowth stages

			Treatment[1]				
Parameter	Harvest*	Plant parts	HS 1	HS 2	HS 3	HS 4	SEM
DM Proportion	First	Growing bud	46.7^{a}	37.4^{b}	38.3^{b}	41.3^{ba}	1.77
(g kg^{-1} DM)		Leaf	292.2^{a}	250.6^{bc}	245.5^{c}	272.1^{ba}	5.17
		Branch	190.8^{c}	231.5^{a}	230.4^{a}	210.0^{b}	3.41
		Bark	113.5^{a}	89.7^{cb}	96.2^{b}	84.3^{c}	2.31
		Stem	356.8^{b}	390.9^{a}	389.8^{a}	392.4^{a}	5.52
	Second	Growing bud	67.6^{b}	51.7^{c}	59.9^{bc}	125.1^{a}	4.72
		Leaf	421.7^{b}	365.4^{c}	387.6^{bc}	466.9^{a}	8.62
		Branch	220.4^{b}	196.7^{b}	230.8^{b}	315.4^{a}	9.04
		Bark	67.9^{a}	79.6^{a}	74.5^{a}	26.6^{b}	3.85
		Stem	222.5^{b}	306.7^{a}	247.2^{b}	70.2^{c}	15.21
Crude Protein	First	Growing bud	215.2^{b}	205.8^{b}	214.9^{b}	231.2^{a}	0.57
(g kg^{-1} DM)		Leaf	221.1	215.7	219.8	231.9	0.48
		Branch	94.8	87.1	93	91.9	0.15
	Second	Growing bud	227.4	227.5	241.0	236.1	0.32
		Leaf	214.5^{b}	224.1^{ba}	235.3^{a}	229.6^{a}	0.42
		Branch	100.9	97.5	109.5	106.4	0.24

Means within a row with different letters are significantly different

[1] HS 1 (3 harvests per year at 4 moths stage), HS 2 (2 harvests per year at 6 months stage), HS 3 (one harvest at 8 month and a 2nd harvest after 4 months) and HS 4 (one harvest of 10 months and a 2nd harvest after 2 months)

* First harvest covers durations at which the plots were subjected to their respective treatments (harvesting stages) each year while second harvest was made to clear all the plots once at the beginning of the main rainy season (end of June) to prepare for subsequent year treatments response evaluation.

Wilt (root rot) caused by *Fusarium sp)* especially in areas with drainage problem was an important disease that affect tagasaste establishment (Berhe and Tothill 1997). *Phytophthora* (Jarrah dieback) was also identified as potential disease under waterlogged condition (Wiley, 2000b). In this study young seedlings and regrowths were very sensitive to frost attack in which plants were either severely damaged (often died) or their productivity was significantly reduced. In the present study the effect of diseases was low but more than 95% of the seedlings have died either due to frost or physical damages during harvesting. By the end of third year, persistency of tagasaste plants were 73, 83, 79, and 82% for the harvesting stages treatments of HS1, HS2, HS3 and HS4, respectively. Though the survival of plants was decreasing with age, tagasaste had good persistence and stayed productive for longer periods.

Conclusions

This study has shown that tagasaste can successfully be established by transplanting seedlings in the highlands of Ethiopia and its subsequent productivity can be substantially improved by applying a good harvesting management. The amount and distribution of rainfall and the occurrence of frost were major factors limiting the performance of tagasaste in cooler areas. For efficient utilization of available rainfall and better regrowth performance in cooler highlands, tagasaste should be pruned before the onset of the main rainy season (end of June). Moreover, harvesting regrowths at 6 (2 times a year) and 10 months stage (one harvest and a second harvest after 2 months) produced the highest annual biomass, edible forage and crude protein yield. Biomass productivity was found highest during the main rainy season followed by short rainy season and lowest during the dry season. Tagasaste productivity increased up to 4 years of age and showed a very good persistency but needs further investigation on persistence and productivity of tagasaste over years. Disease and pest attacks were not major problems. Further evaluation of the nutritional characteristics, designing strategies in fitting the harvesting management practices to the cropping and farming systems and feeding schemes in the tropical highlands would improve the overall efficiency of agricultural productivity in mixed crop-livestock production system of smallholders in tropical highlands.

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