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Biomass yield, nutrient content and *in vitro* dry matter digestibility of morphological fractions of two sweet potato varieties intercropped with coffee or maize-haricot bean

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Effects of stages of growth and intercropping of two sweet potato varieties (Hawassi-83 and Tula) (alone or with coffee or maize-haricot bean) on biomass yield and *in vitro* dry matter digestibility (IVDMD) of morphological fractions were assessed in Southern Ethiopia. Similar coffee plantations (age, density, soil type, topography) were selected for intercropping. Vines were planted on three plots per intercropping type at 15 days interval, and cultivated three times. Morphological fractions were collected from 1.0 m^2 of land on 4th, 5th and 6th months for nutrient and partial budget analyses (revenue estimated for 100 m^2 of land). Ten elders evaluated varieties at 2nd, 4th and 6th months after planting. Lowest DM (77 g/kg) was obtained from fresh Tula stem-petiole (FTSP) but highest (190 g/kg) from fresh Tula leaf (FTL) ($p<0.05$). Fresh Tula vine (FTV) had lowest (840 g/kg DM) organic matter and FTL ($p<0.05$) highest (914 g/kg DM). Crude protein content of fresh Hawassi-83 stem-petiole (FHSP) was lowest (113 g/kg DM) but that of FTL highest (269 g/kg DM). Lowest vine yield (0.27 kg/m^2) was from Tula intercropped with coffee but highest (0.82 kg/m^2) from maize-haricot bean intercropping followed by sole Hawassi-83 (0.56 kg/M^2). Overall mean vine DM yield (333.6 g/m^2) of maize-haricot bean intercropping was greater ($p<0.05$) than that of intercropping (174.0 g/m^2) with coffee. IVDMD of fresh Hawassi-83 leaf (FHL) (78.0±0.27) and FTSP (77.0±0.10) were lowest but that of FHSP (84.3±0.59) and FTL (84.3±0.04) highest. Both Hawassi-83 and Tula vine were best produced when intercropped with maize-haricot bean, although Hawassi-83 was more profitable and preferred by respondents than Tula.

Key words: Intercropping, morphological fractions, nutrients, stage of maturity, sweet potato vine.

INTRODUCTION

Ethiopia owns 55,027,280 cattle, 27,347,933 sheep, 28,163,332 goat, 1,963,010 horses, 6,953,077 donkeys, 356,087 mules, 1,098,312 camels, 51,350,738 poultry and 5,052,297 beehives (CSA 2013/14) which play crucial role by contributing 15 to 17% of GDP, 35 to 49% of agricultural GDP and 37 to 87% of household incomes

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(ILRI, 2010).

The huge livestock population is constrained by insufficient and poor quality feed. Natural pastures and poor quality crop residues are the main sources of livestock feed in East Africa. However, grazing lands do not fulfill the nutritional requirement of animals particularly in dry seasons (Zinash et al*.,* 1995). With the rapid increase in human population and high demand for food, pastures are steadily being converted to crop lands. Less productive marginal lands unsuitable for cultivation are left for grazing. Deforestation and overgrazing has also substantially reduced soil fertility and productivity (Alemayehu, 1999). The limited land available for feed and fodder production and poor quality pasture demanded total dependence of livestock on crop residues and by-products (Firew, 2001). Assessing forage production options in the limited land available is of paramount importance to mitigate this constraint.

In this study, the effect of stage of growth and intercropping of sweet potato with coffee or maize-haricot bean on biomass yield of morphological fractions of sweet potato and profitability of intercropping were assessed.

MATERIALS AND METHODS

Description of the study area

The study was conducted in Shebedino district of Sidama Zone, Southern Nations, Nationalities and People's Regional State (SNNPRS) of Ethiopia. Leku the capital city of the district is situated 290 km south of Addis Ababa and 27 km south of Hawassa. The study area shares common border with Hawassa town, Dale, Gueriche and Borecha Districts (SWAO, 2013). Shebedino district was selected on the basis of availability of sweet potato and suitability of agro-ecology for experimental plants and accessibility to the Hawassa University working facilities.

The District is 197.1 km^2 and 1800 to 2950 m. a. s. l. It receives 900 and 1500 mm rainfall annually between June-September and February-April. Mean temperature of the District ranges between 16 to 25°C. It has two agro-ecological zones: Dega in the range of 2500 to 2812 m. a. s. l (9.4% and has 4 Kebeles) and Weinadega in the range of 2000 to 2499 m.a.s.l. (90.4% and has 31 Kebeles), of these 3 Kebeles are in town and 32 in rural.

Intercropping plantation

Coffee plants which have similar age, number of coffee plants per 1200 m^2 on each farmer's land, relatively similar landscape, soil type and management for intercropping types (sole sweet potato, coffee and maize + haricot bean) were selected for intercropping. Four farmers were selected and an agreement was made with them for land preparation, plantation and management. A plot size of 1200 m^2 per farmer was sub divided in to three equal parts for successive plantation. The land was ploughed two times and vine seed of Hawassi-83 and Tula varieties were purchased for sequential plantation. Each variety under each farmer was planted on 200 m^2 of land first in 18 July, 2013. The second and third rounds were carried out on the same size plots at 15 days interval. Total planted area was 4800 m^2 (200 m^2 × 2 varieties × 3 planting interval × 4 farmers) was ploughed 3 times during growth period.

Farmers were selected to evaluate the biomass productivity and early maturity, viability and land cover based on their experiences of sweet potato production and using it as source of feed, food and income. The evaluators examined the fields three times (2nd, 4th and 6th month of growth). Fresh samples from each variety were collected from 1 m^2 at 4, 5 and 6 months of age (early, medium and maturity stages) for nutrient and biomass determination and partial budget analysis.

Chemical analysis

Dry matter and ash were determined according to AOAC (1990), nitrogen (N) content was determined by the Kjeldhal procedure and crude protein (CP) was calculated as N*6.25. Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were analyzed according to Van Soest et al. *(*1991).

In vitro dry matter digestibility (IVDMD)

In vitro studies were conducted to estimate the potential digestibility of the pooled sub-samples of each of the 4 round forage cuts. The IVDMD was determined using the two stages *in vitro* Tilley and Terry procedure (1963) as modified by Van Soest and Robertson (1985).

Partial budget analysis

The three land types were assessed for comparative advantages based on samples taken on 100 m^2. All produces on the plots were recorded across the trial period. Income from coffee (non-processed beans), maize and haricot bean grains and byproducts and all costs (labor, seed, vine, tuber, etc) were estimated based on seasonal prices on local market. The price of vine and tuber were taken as constant values.

Partial budget analysis was conducted for measuring profit margin of intercropping (Upton, 1979). Net income (*NI*) was calculated as total return (TR) minus total variable cost *(TVC)*:

$$NI = TR - TVC$$

Change in net income *(ΔNI)* was calculated as change in total return *(ΔTR*) minus change in total variable cost *(ΔTVR):*

$$\Delta NI = \Delta TR - \Delta TVR$$

Marginal rate of return *(MRR)* as a measure of increase in net income *(ΔNI)* associated with each additional unit of expenditure *(ΔTVC)* was calculated as

$$MRR = (\Delta NI / \Delta TVC) \times 100$$

Data management and statistical analysis

Nutrient contents, biomass yield (DM and OM) and IVDMD of the morphological fractions and qualitative evaluation of the morphological fractions of the sweet potato varieties harvested from three intercropping at three stages of maturity were subjected to ANOVA using General Linear Model (GLM) procedure of SPSS Version 22 (SPSS, 2014). Productivity of the land used for sweet potato intercropping was subjected to descriptive statistics. Means were separated using Duncan's Multiple range test at p<0.05.

The model for analysis of variance was $Yijk = \mu + \alpha i + \theta j + \beta k + \alpha i\theta j + \alpha i\beta k + \theta j\beta k + \alpha i\theta j\beta k + eijk$ where: *Yijk* = DM and OM content/yield IVDMD (i=vine, leaf and stem with petiole); at three stages of maturity (j = 5^{th}, 6^{th} and 7^{th} months of age of sweet potato) and four

Table 1. Dry matter and organic matter contents of morphological fractions (vine, leaf and stem-petiole) of the two varieties (Hawassi-83 and Tula) cut at three stage of growth.

Parameter	Stage of growth (months)	Morphological fractions						Overall mean	p- value
		FHV	FHL	FHSP	FTV	FTL	FTSP		
DM (g/kg)	4	139^{aC}	158^{aD}	142^{C}	124^{aB}	188^{E}	76^{A}	138±7	0.0000
	5	142^{abC}	162^{aD}	143^{C}	133^{bB}	190^{E}	79^{A}	142±6	0.0000
	6	149^{bC}	168^{bD}	143^{C}	133^{bB}	191^{E}	76^{A}	143±7	0.0000
	Mean	143^{C}	163^{D}	143^{C}	130^{B}	190^{E}	77^{A}	141±7	0.0000
	SEM	6	2	0	2	1	1		
	p-value	0.051	0.0080	0.422	0.0173	0.8464	0.1781		
OM (g/kg DM)	4	863^{aA}	860^{A}	862^{A}	853^{A}	915^{B}	863^{aA}	869±4	0.0000
	5	872^{bB}	855^{B}	863^{B}	835^{A}	913^{C}	853^{aB}	865±5	0.0000
	6	869^{bB}	858^{B}	863^{B}	833^{A}	913^{C}	848^{bB}	863±5	0.0000
	Mean	868^{B}	858^{B}	863^{B}	840^{B}	914^{A}	855^{B}	866±5	0.0000
	SEM	5	6	2	7	2	9		
	p-value	0.0096	0.2205	0.9063	0.0051	0.1250	0.0063		

Column means bearing different lowercase superscript letters are significantly different and row means bearing different uppercase superscript letters are significantly different ($p<0.05$). FHV, fresh Hawassi-83 vine; FHL, fresh Hawassi-83 leaf; FHSP, fresh Hawass-83i stem with petiole; FTV, fresh Tula vine; FTL, fresh Tula leaf; FTSP, fresh Tula stem with petiole; DM, dry matter; OM, organic matter, SEM, standard error of mean.

intercropping types (k= sole sweet potato, sweet potato intercropped with coffee and sweet potato intercropped with maize-haricot bean); μ = over all mean; αi = effect of morphological fractions on DM and OM content/yield and IVDMD; θj = effect of stage of maturity on DM and OM content/yield and IVDMD; βk = effect of intercropping on DM and OM content/yield and IVDMD; $\alpha i\theta j$ = interaction effect among the morphological fractions and three stages of maturity on DM and OM content/yield and IVDMD; $\alpha i\beta k$ = interaction effect among the morphological fractions and three intercropping types on DM and OM content/yield and IVDMD; $\alpha i\theta j\beta k$ = interaction effect among the morphological fractions, three stages of maturity and three intercropping types on DM and OM content/yield and IVDMD; *eijk* = random error

RESULTS

Nutrient content, biomass yield and *in vitro* dry mater digestibility of the sweet potato varieties

Dry matter and OM yield of morphological fractions cut at three stages of maturity are depicted in Table 1. The DM content of FHL and FTV at 3rd stage of growth was greater ($p<0.05$) than at 1st and 2nd; FTV having the least ($P<0.05$) at 1st stage of growth. The rest of the morphological fractions were similar in DM content at all stages of maturity. The OM content of all the morphological fractions of the two varieties cut at three stages of growth were similar ($p>0.05$).

The overall mean dry matter (DM) and organic matter (OM) yields of vines of the two sweet potato varieties intercropped with coffee and maize-haricot bean and cut at three stages of maturity is depicted in Table 2. Both DM and OM yields of vines of sweet potato intercropped with maize-haricot bean were highest of the other two intercropping ($p<0.05$).

The overall nutrient content of mixtures of the respective morphological fractions from the two sweet potato varieties under three intercropping and the three stage of maturity is depicted in Table 3. The DM content of FHL was greater than that of FHV and FHSP; and DM differences of morphological fractions of Tula were wide; FTSP had the lowest but FTL the highest. Leaf parts of the two sweet potato varieties had greater DM than vine and stem with petiole. The lowest OM content was in FTV but FTL had highest OM content of FTV and FTSP and all fractions of Hawassi-83.

The CP contents of FHSP were the least but the highest in FTL. EE content in both varieties of FHL, FTL and FTSP were the least but highest in FTV. The least NDF was in FTL but the highest was in FTSP. The ADF content of FTL was the least of all but that of FTSP was the highest. The least ADL was in FTL but the highest was in FHSP. The IVDMD of FHL and FTSP were similar and much lower than that of FHSP whereas FTL the FHV come in between.

Qualitative evaluation and partial budget analysis

As shown in Table 4 majority of evaluators/respondents ($p<0.05$) preferred Hawassi-83 to Tula in biomass productivity and yield, adaptability to intercropping, early maturity and marketability of the tuber. Farmers can reasonably evaluate crops according to the current local situation and benefits.

Table 2. Dry matter and organic matter yields of vines of the two sweet potato varieties produced under three intercropping types.

Yields	Intercropping types			SE	p
	Sole sweet potato	Sweet potato-coffee	Sweet potato-maize-haricot bean		
Dry matte (g/M²)	252^{b}	174^{a}	334^{c}	22	0.0000
Organic matter (g/M^2)	217^{b}	149^{a}	286^{c}	20	0.0000

Least square means within a row bearing different superscript letters are significantly different.

Table 3. The pooled nutrient content and *in vitro* DM digestibility (Mean ±SE) of the morphological fractions of Hawassi-83 and Tula harvested at three stages of maturity from three intercropping types.

Nutrient (g/kg DM)	Morphological fractions of sweet potato						Overall mean	p-value
	FHV	FHL	FHSP	FTV	FTL	FTSP		
DM (g/kg)	$143±20^{c}$	$163±7^{d}$	$143± 1^{c}$	$130±7^{b}$	$190±6^{e}$	$77±5^{a}$	141±2	0.0000
Ash	$133±14^{b}$	$141±17^{c}$	$138±3^{c}$	$160±23^{d}$	$85±2^{a}$	$144±28^{c}$	134±3	0.0000
CP	$176±1^{c}$	$243±0^{de}$	$113±1^{a}$	$222±1^{d}$	$269±1^{e}$	$134±0^{b}$	193±3	0.0000
EE	$127±2^{c}$	$83±0^{a}$	$124±3^{c}$	$152±0^{d}$	$99±1^{b}$	$85±0^{a}$	112±2	0.0000
NDF	$345±32^{c}$	$311±26^{b}$	$349±0^{c}$	$350±20^{c}$	$276±47^{a}$	$416±1^{d}$	341±2	0.0000
ADF	$207±4^{c}$	$169±1^{b}$	$249±1^{d}$	$215±2^{c}$	$139±3^{a}$	$290±3^{e}$	212±2	0.0000
ADL	$170±0^{c}$	$114±0^{b}$	$193±2^{d}$	$171±1^{c}$	$99±3^{a}$	$183±3^{d}$	155±2	0.0000
Digestibility (g/kg DM)								
IVDMD	$809±1^{b}$	$780±3^{a}$	$843±6^{c}$	$824±0^{bc}$	$843±0^{c}$	$770±1^{a}$	812±2	0.0000

DM, dry matter; CP, crude protein; EE, ether extract; NDF, neutral detergent factor; ADF, acid detergent factor; ADL, acid detergent lignin; IVDMD, *in vitro* dry matter digestibility; FHV, fresh Hawassi-83 vine; FHL, fresh Hawassi-83 leaf; FHSP, fresh Hawassi-83 stem with petiole; FTV, fresh Tula vine; FTL, fresh Tula leaf; FTSP, fresh Tula stem with petiole.

Table 4. Qualitative evaluation of Hawassi-83 and Tula of the respondents in the study area (N=10).

Parameter	Values			Test	
	Hawassi-83 N (%)	Tula N (%)	Total N (%)	χ2	*p-value*
Biomass (vine and tuber) yield	$9 (90)^{b}$	$1(10)^{a}$	10(100)	10	0.002
Better yielder in inter-cropping	7(70)	3(30)	10(100)	10	0.002
Tuber palatability	$9(90)^{b}$	$1(10)^{a}$	10(100)	10	0.002
Short maturation time	8(80)	2(20)	10(100)	10	0.002
Marketability	7(70)	3(100)	10(100)	10	0.002
Overall	$40(78)^{b}$	$10(22)^{a}$	50(100)	50	0.000

Row values with different superscript letters are significantly different. N= number of respondents.

The total revenue obtained after six months of the trial from different intercropping is depicted in Table 5. The products from sole sweet potato cultivation are vine and tuber but from the intercropping coffee, maize grain and haricot bean are also included. Sole plantation or intercropping of Hawassi-83 was more profitable than those of Tula. Sweet potato intercropping with maize-haricot bean was more profitable than with coffee.

DISCUSSION

The studies of Tesfaye et al. (2011) have shown that the DM content of unspecified sweet potato variety was 92% but neither of the DM contents of vines from the varieties in this study agreed with this value. Netsanet (2006) reported DM of unspecified variety of sweet potato vine, leaf and stem were 21.05, 21.7 and 18.67%, respectively but only the leaf part was close to the DM content of FTL. The study of Tesfaye and Amenti (2008) on Hawassi-83 vine was lower in DM content than result obtained in this study, which may be attributed to differences in stage of maturity, types of treatment and soil type.

The DM of FTSP was the least but that of FTL the highest. Leaves of the two sweet potato varieties harvested at third stages of growth varied in DM content

Table 5. Productivity of the two sweet potato varieties intercropped on farmers' land (800 M^2) during June- March, 2013

Parameters	Intercropping type																	
	Sole sweet potato				Sweet potato-coffee						Sweet potato-maize-haricot bean							
Variety	Hawassi-83		Tula		Hawassi-83			Tula			Hawassi-83				Tula			
Product type	Vine	Tuber	Vine	Tuber	Vine	Tuber	Coffee	Vine	Tuber	Coffee	Vine	Tuber	Maize	HB	Vine	Tuber	Maize	HB
Fresh (kg)	445	960	286	182	288	360	45	218	69	50	653	216	224	80	308	142	224	132
Cost (Birr/kg)	667	3840	429	728	432	1440	227	327	277	252	980	864	1343	480	462	568	1344	795
Sums of revenue (Birr)	4508		1157		2099			856			3667				3169			
Return due to intercropping (Birr/M^2)	5.63		1.44		2.62			1.07			4.58				3.96			
Return due to intercropping (Birr/M^2)	3.53				1.84						4.27							

with no visible trend in the rest of the fractions; while similar trend was observed in DM yield between FTV and FHV at last stage of growth; the rest of the fractions showed no differences. The highest DM and OM yields were obtained from sweet potato maize-haricot bean intercropping.

The OM of FTV and FTSP was the least but that of FTL the highest. All morphological fractions within a species showed no difference in OM in the three stage of growth. The OM content of vine and leaf earlier reported (Netsanet, 2006) nearly agreed with the results of this study but not of the stem. The study of Tesfaye and Amenti (2008) on Hawassi-83 vine was lower in OM content than this study but nearly agreed with OM content of FTV and Hawassi-83 with Kudade in their study.

The CP was the highest but EE the lowest in FHL and FTL. The CP and EE contents were inversely related in the morphological fractions. The CP content of FHSP and FTSP were the least compared to vines and leaves which agrees with earlier results reported (Etela and Oji, 2009). The CP content of FHL and FTL were the highest compared to vine and stem with petiole in both varieties and agrees with earlier results (Etela and Oji, 2009; Netsanet, 2006; Orodho et al., 1993) but disagrees with that of Tesfaye et al. (2011). The CP contents of FHL and FTL were greater than 20% which agrees with the study of Orodho et al. (1993) it was higher than the finding (20.9% CP on DM basis) of Woolfe (1992) stated for sweet potato green. The CP content of the vine was greater than CP content of all other parts (FAO, 1994). Tesfaye and Amenti (2008) reported higher CP content of Hawassi-83 vine than that of FHL but nearly agreed with the CP content of Falaba Damota which could be attributed to differences in parts examined, soil type, stage of maturity and sweet potato varieties.

The NDF value of FTSP agreed with the NDF value reported of sweet potato stem (Netsanet 2006) but disagreed with that of Etela and Oji (2009) in which leaf blade had the highest NDF. The study of Tesfaye and Amenti (2008) on Hawassi-83 vine was lower than that of FHV and FTV of this study. The NDF content of FTL nearly agrees with that of Hawassi-83; FHL with that of Koka-12 and FTV with that of Belela.

The ADF content of FTL was the least of all but that of FTSP was the highest which generally disagrees with earlier report (Netsanet, 2006). The study of Tesfaye and Amenti (2008) on Hawassi-83 vine was higher in ADF content than FHV in this study but it nearly agreed with Halaba and Damote; and that of FHSP in this study agrees with Koka-12 and FTSP with Bereda and Belela. The ADL content of sweet potato stem earlier reported (Netsanet, 2006) agrees with the results of this study. None of the ADL contents in this study agree with the findings of Tesfaye et al. (2011).

The least CP and higher ADL contents in FHL are possible reasons for reduced digestibly but in the FTL the higher CP and least ADL contents must have been in favor of the highest digestibility rate. As the ADL content increased in Hawassi-83, digestibility increased but the opposite happened in Tula. In Hawassi-83, as the CP content increased, the digestibility decreased but the opposite happened in Tula parts. The FHSP was more digestible than FHV but FTL was more digestible than FTV. Vines in both varieties had lower IVDMD which agrees with the results of an earlier study (Netsanet, 2006).

The highest DM, CP and IVDMD and lowest NDF, ADF and ADL were from FTL but medium DM, highest CP and lowest ADL and IVDMD were from FHL. The low ADL in FHL suppressed

IVDMD but in FTL it favored IVDMD however in FHSP, the ADL and IVDMD were linearly related.

Hawassi-83-maize-haricot bean intercropping gave better land productivity, vine biomass and total revenue; possibly due to improved soil fertility by nitrogen fixation of haricot bean and thus to overcome the critical land and feed shortage and reduced land productivity of the district and region, intercropping sweet potato with maize-haricot bean should be promoted.

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Conflict of Interests

The authors have not declared any conflict of interests.

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