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Evaluation of Vetch Species and their Accessions for Agronomic Performance and Nutritive Value in the Central Highlands of Ethiopia

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Abstract

Twenty accessions of five vetch species were evaluated for agronomic and nutritional attributes at Holetta and Ginchi in the central highlands of Ethiopia during 2009 main cropping season. The experiment was conducted in randomized complete block design with three replications. Most measured parameters revealed significant (P<0.05) difference between the treatments and locations. Vicia narbonensis and Vicia sativa were erect, short plant height and early maturing for both forage and seed yields, while Vicia dasycarpa, Vicia villosa and Vicia atropurpurea have creeping growth habit, tall plant height and intermediate to late maturity for forage and seed yields. Taller species gave better forage dry matter yield while early maturing species have higher seed yield and thousand seed weight and the difference between the highest and the lowest was 0.4 and 0.9 t/ha for seed yield and 178.7 and 199.7g for thousand seed weight at Holetta and Ginchi respectively. Among vetch species, Vicia dasycarpa have higher crude protein and digestibility but lower fiber contents. Correlation analysis indicated that forage dry matter yield was positively associated with days to forage and seed harvests, plant height, crude protein and digestibility. The result of this study is important for mixed cropping with food crops.

Keywords: vetch species, accessions, genetic variation, agronomic trait, nutritional trait

Introduction

The central highland of Ethiopia is characterized by crop-livestock mixed farming systems. Livestock is an integral component of the agricultural activities in the country. The share of the livestock sub sector contribution in the national economy is estimated to be 12-16% to the total Gross Domestic Product (GDP), 30- 35% to the agricultural GDP (Ayele *et al.,* 2002); 19% to the export earnings (FAO, 2003); and 31% of the total employment (Getachew, 2003). Despite enormous contribution of livestock to the livelihood of farmers, poor availability of good quality feed remains to be the major bottleneck to livestock production in the highlands of Ethiopia. The number of well adapted annual forage legumes in the highlands of Ethiopia is comparatively lower than the mid and low altitudes species due mainly to climatic factors restrictions.

Among the annual forage legumes, vetches are well adapted and more promising as short term fodder crops. One attraction of vetch is its versatility, which permits diverse utilization as either ruminant feed or green manure. It grows well on the reddish brown clay soils and the black soils of the highland areas. It has been grown successfully in areas with acid soil with pH of 5.5-6. Forage legumes including vetches are rich sources of N for livestock with cheaper prices compared to concentrates especially in developing countries (Seyoum, 1994). Getnet and Ledin (2001) also found that vetch has a higher crude protein content compared to many other tropical herbaceous legumes. Contribution of vetch in crop-livestock production systems in different parts of the world is well recognized. Its high value, as protein supplement for ruminants on low quality diets has been recorded (Berhanu *et al*., 2003).

Currently, with the rapid increase in human population and demand of food, grazing lands are steadily shrinking in favor of their conversion to arable lands. As a result availability of adequate feeds has become a major setback for increased livestock production. According to Berhanu *et al*., (2003) improved nutrition through adoption of sown forage could substantially increase livestock productivity. Getnet *et al*., (2003) reported that food-forage crops integration with different methods (non-conventional forage production systems) are important and appropriate in areas where land shortage is a problem and the agricultural production system is subsistence. Integration of forage legumes into the cereal-based cropping system through different methods is one of the strategic interventions for optimizing the productivity of a given land use system (Tarawali *et al*., 2002).

Information on plant height, days to maturity, growth habit and other growth characteristics of the forage legumes are important to integrate with food crops in mixed stands. Previous evaluations of vetches has been limited to adaptation and biomass yield but there is no adequate assessment of different vetch species and accessions with respect to growth features, forage and seed productivity, forage quality, and digestibility. Accordingly, there is a need to evaluate vetches for basic quantitative and qualitative traits. Therefore, this study was executed with the following objectives: 1) to evaluate the productivity of vetch species and their accessions at Holetta and Ginchi, 2) to determine the differences among a wide array of accessions in morphological, agronomical and nutritional parameters of different vetch species, and 3) to compare the performance of the vetch species and their accessions under two major soil types and climatic conditions.

Materials and Methods

Description of the study sites

The experiment was conducted at Holetta Agricultural Research Center (HARC) and Ginchi sub center in the central part of Ethiopia. HARC is located at 9°00'N latitude, 38°30'E longitude at an altitude of 2400 m above sea level. It is 34 km west of Addis Ababa on the road to Ambo. It receives 1055 mm mean annual rainfall, average relative humidity of 60.6%, and average maximum and minimum air temperature of 22.2°c and 6.1°c respectively. The soil type of the area is predominantly red Nitosol. Ginchi sub center is located at 75 km west of Addis Ababa on the way to Ambo. It is situated at 9°02'N latitude and 38°12'E longitude with an elevation of 2200 m above sea level, and receives average annual rainfall of 1095 mm, average relative humidity of 58.2%, and average maximum and minimum air temperature of 24.6°c and 8.4°c respectively. The soil of the area is predominantly black clay Vertisol.

Experimental treatments and design

The study was executed using twenty accessions from five different vetch species (Table1). The experiment was conducted on a randomized complete block design with three replications. Seeds were sown in rows spaced 30 cm on a plot size of 2.4 m x 4 m= 9.6 m^2. The treatments were sown according to their recommended seeding rates: 25 kg ha^{-1} for *Vicia villosa*, *Vicia dasycarpa* and *Vicia atropurpurea*; 30 kg ha^{-1} for *Vicia sativa* and 75 kg ha^{-1} for *Vicia narbonensis*. At sowing, 100 kg ha^{-1} diammonium phosphate (DAP) fertilizer was uniformly applied for all treatments at both locations. At Ginchi site, sowing was done on camber-beds to improve drainage and reduce water-logging problems of vertisol.

Data collection

Data were collected on days to forage harvest, seed harvest, plant height, forage dry matter (DM) yield, seed yield, thousand seed weight and nutritive value. Seed yield and thousand seed weight were calculated at 10% moisture content. The oven dried biomass yield samples were ground to pass through a 1 mm sieve size for nutritional analysis. The samples were analyzed in % DM basis using a calibrated Near Infra Red Spectroscopy (NIRS) Foss 5000 apparatus and Win ISI II software. The samples from different vetch species and their accessions were analyzed using conventional method to calibrate the NIRS apparatus for analysis of more samples from vetch species and their accessions. Samples were dried at 60^{o}c overnight in an oven to standardize the moisture content and then 3g of each sample was scanned using the NIRS at 1108- 2492 nm, with an 8 nm step. The method was known to be one of the more multifaceted robust applications to estimate chemical entity and parameters like digestibility of organic matter in the dry matter which is usually estimated by bioassays (Fekadu *et al*., 2010). The crude protein (CP) yield was calculated by multiplying CP content with total dry biomass yield and then divided by 100.

Table1. Accessions of five different vetch species used as treatments for this experiment

Treat. No.	Species	Accessions	Treat. No.	Species	Accessions
1	*Vicia sativa*	64266	1	*Vicia villosa*	2434
2	*Vicia sativa*	61904	2	*Vicia villosa*	2446
3	*Vicia sativa*	61744	3	*Vicia narbonensis*	2384
4	*Vicia sativa*	61509	4	*Vicia narbonensis*	2387
5	*Vicia sativa*	61039	5	*Vicia narbonensis*	2376
6	*Vicia sativa*	61212	6	*Vicia narbonensis*	2392
7	*Vicia villosa*	2565	7	*Vicia narbonensis*	2380
8	*Vicia villosa*	2450	8	*Vicia dasycarpa*	Namoi
9	*Vicia villosa*	2424	9	*Vicia dasycarpa*	Lana
10	*Vicia villosa*	2438	10	*Vicia atropurpurea*	Atropurpurea

Statistical analysis

Analysis of variance (ANOVA) procedures of SAS general linear model (GLM) was used to compare treatment means (SAS, 2002). Bartlett's test for homogeneity of variance was carried out to determine the validity of individual experiment. Different transformation methods were used to transform those data which couldn't exhibit homogeneity of variance for agronomic and nutritional parameters according to Gomez and Gomez (1984). Accordingly, data based on days to forage harvest, plant height at forage harvest, dry matter yield, seed yield and thousand seed weight were log-transformed whereas neutral detergent fiber and crude protein were square root-transformed for statistical analysis and untransformed means were presented according to Gomez and Gomez (1984). Duncan Multiple Range Test (DMRT) at 5% significance was used for comparison of means. The Pearson correlation analysis procedure of the SAS statistical package was applied to measure the strength of linear dependence between any two measured variables. The data were analyzed using the following model: $Y_{ijk} = \mu + T_i + L_j + (TL)_{ij} + B_{k(j)} + e_{ijk}$ Where, Y_{ijk} = measured response of treatment i in block k of location j, μ = grand mean, T_i = effect of treatment i, L_j = effect of location j, TL= treatment and location interaction, $B_{k(j)}$ = effect of block k in location j, and e_{ijk} = random error effect of treatment i in block k of location j.

Results and Discussion

Effect of location on vetch performance and interaction effects

The two locations displayed significant (P<0.05) differences for a number of agronomic and nutritional characters for different vetch species and their accessions (Table 2). Species by location interaction and accessions by location interaction effects also revealed significant differences (P<0.05) for most observed characters (Table 3). When significant, the interaction effects were mostly a "cross-over" type; i.e. interactions were associated with rank order changes among the species and accessions of vetch. This indicated that the two locations were distinctly different for some of the characters and that better vetch species and their accessions at one location may not also be better performing at another. According to Gemechu (2012), when genotypes perform consistently across locations, on the other hand, breeders are able to effectively evaluate germplasm with a minimum cost in a few locations for ultimate use of the resulting varieties across wider geographic areas. However, with high genotype by location interaction effects, genotypes selected for superior performance under one set of environmental conditions may perform poorly under different environmental conditions (Ceccarelli, 1997). Therefore, it could be implicated that selection of better performing genotypes at one location may not enable the identification of genotypes that can repeat nearly the same performances at another location.

Days to forage and seed harvests

Days to forage harvest for species of vetch showed significant (P<0.05) difference at both locations (Table 4). The result indicated that 83.3 to 112.2 and 96.8 to 124.7 days were required after emergence of the seedlings for forage harvest at Holetta and Ginchi respectively. *Vicia narbonensis* was significantly early (P<0.05), while *Vicia atropurpurea* was significantly late (P<0.05) for forage harvest at both locations. Getnet *et al*., (2003) also reported that species such as *Vicia narbonensis* and *Vicia sativa* are relatively early maturing than the other vetches. On the other hand, days to forage harvest for accessions showed significant (P<0.05) difference at Holetta and Ginchi (Table 7). This difference in maturity period is an important agronomic trait to select companion crops in mixed fodder systems for maximum production. Getnet *et al*., (2003) also reported that days to maturity had an advantage of selecting companion crops that best synchronize to the days to maturity for better compatibility and forage yield. Late maturing varieties stay green for longer period of time so farmers get green feed for their livestock for longer period. On the other hand, early maturing varieties could be raised in short rains to feed the livestock during the critical period of feed shortage. When late maturing oats varieties were sown in mixture with late maturing vetch species, like *Vicia villosa*, compatibility was good compared with early maturing oats variety (Getnet, 1999).

Days to seed maturity of species also showed very similar trend to days to maturity for forage at both locations (Table 4). *Vicia narbonensis* showed significantly earlier ($P<0.05$) than the remaining species at both locations. Variation in phenology of vetch species and their accessions has a great effect on forage and seed yield productivity. According to Fekede (2004), early maturing oats varieties can progress through different developmental stages at a faster rate than late maturing varieties and may be useful for double cropping system in chickpea/grass pea growing highland areas when the chickpea/grass pea is grown using residual moisture in October. The author also reported that oats varieties with such qualities are highly preferable in improved forage adoption efforts because they can be introduced without disturbing the farming system and enable the farmers to get an added benefit from the same plot of land. Getnet *et al*., (2003) also reported that early maturing oats varieties could be utilized during the short rains and using residual moisture were in both cases moisture is usually not reliable to cultivate other food crops. According to Richards (1991), crop phenology is the most important single factor influencing yield and adaptation particularly where growth factors are limited. Generally, variation in forage and seed maturity periods of different vetch species and their accessions over the testing sites need careful selection of the plants to be sown in a particular soils and climatic conditions.

Table 2. Mean performance of measured agro-morphological and quality traits of different vetch species (a) and accessions (b) at two locations in Ethiopia

Traits	Locations		Mean	CV (%)
	Holetta	Ginchi		
(a) Vetch species				
Days to forage harvest$^{\Phi}$	101.04^{b}	111.95^{a}	106.50	0.85
Days to seed harvest	129.62^{b}	152.00^{a}	140.81	4.04
Plant height at forage harvest$^{\Phi}$	113.82^{b}	130.98^{a}	122.40	4.08
Dry matter yield t/ha$^{\Phi}$	4.56^{b}	6.09^{a}	5.33	21.09
Neural detergent fibre^{4}	48.48^{a}	43.81^{b}	46.15	10.23
In-vitro DM digestibility	66.47^{a}	66.31^{b}	66.39	0.14
Crude protein^{4}	22.39^{a}	22.48^{a}	22.44	0.79
Crude protein yield t/ha	1.02^{b}	1.37^{a}	1.20	29.97
1000 seed weight	81.71^{a}	86.31^{a}	84.01	24.63
Seed yield t/ha$^{\Phi}$	0.62^{b}	2.39^{a}	1.51	8.86
(b) Vetch accessions				
Days to forage harvest$^{\Phi}$	99.25^{b}	109.32^{a}	104.28	0.75
Days to seed harvest	128.98^{b}	150.07^{a}	139.53	3.64
Plant height at forage harvest	103.42^{b}	114.38^{a}	108.90	13.57
Dry matter yield t/ha$^{\Phi}$	4.41^{b}	5.87^{a}	5.14	18.16
Neural detergent fibre^{4}	51.92^{a}	44.64^{b}	48.28	10.21
In-vitro DM digestibility	65.31^{a}	65.15^{b}	65.23	0.13
Crude protein^{4}	21.45^{a}	21.50^{a}	21.48	0.68
Crude protein yield t/ha	0.94^{b}	1.25^{a}	1.10	26.49
1000 seed weight$^{\Phi}$	91.09^{a}	96.47^{a}	93.78	2.21
Seed yield t/ha$^{\Phi}$	0.64^{b}	2.52^{a}	1.58	8.48

Within row means with different superscripts differ significantly (P<0.05); $^{\Phi}$ = Log transformation; ^{4} = Square root transformation

Plant height at forage harvest

Plant height for vetch species at forage harvest showed variation (P<0.05) at both locations (Table 5). The tallest plant height at forage harvest was recorded for *Vicia dasycarpa* followed by *Vicia villosa* and *Vicia atropurpurea* at Holetta. At Ginchi, *Vicia atropurpurea* was the tallest followed by *Vicia dasycarpa* and *Vicia villosa*. *Vicia sativa* and *Vicia narbonensis* were the shortest at both testing sites. Plant height for accessions of vetch at forage harvest also showed significant (P<0.05) difference at both locations (Table 7). There are different methods to integrate forage legumes with food crops. During integration, plant height as well as growth habit should be considered, because they have an impact on compatibility. The vetch species growth habit can be broadly grouped as erect, creeping or climbing. *Vicia dasycarpa*, *Vicia* *villosa* and *Vicia atropurpurea* have creeping or climbing growth habit, whereas *Vicia narbonensis* and *Vicia sativa* have erect growth habit. Vetch species which has an erect growth habit is more compatible with small cereals in intercropping/under-sowing systems while creeping or climbing growth habit has better compatibility with large cereals in intercropping/under-sowing systems. According to Getnet *et al*., (2002), depending on the soil fertility condition, creeping or climbing type of vetches could be successfully intercropped in barley without any significant reduction of the barley yield. However, on soils with high soil P and low acidity conditions, vetches have negative effect on barely grain yield. They also reported that on fertile soil even though the forage yield was low, the erect type of vetch, *Vicia narbonensis* was good in compatibility.

Table 3. Combined analysis of variance for measured agro- morphological and quality traits of vetch species (a) and accessions (b) tested at Holetta and Ginchi

	Mean square				
Traits	L	S	L x S	Mean	CV (%)
(a) Species					
Days to forage harvest$^{\Phi}$	**	**	**	106.50	0.85
Days to seed harvest	**	**	**	140.81	4.04
Plant height at forage harvest$^{\Phi}$	*	**	**	122.40	4.08
Dry matter yield$^{\Phi}$	**	**	NS	5.33	21.09
Crude protein^{4}	NS	**	NS	22.44	0.79
Crude protein yield	**	**	*	1.10	29.97
Neutral detergent fiber^{4}	**	**	**	46.15	10.23
In-vitro dry matter digestibility	**	**	NS	66.39	0.14
Thousand seed weight	NS	**	NS	84.01	24.63
Seed yield $^{\Phi}$	**	**	**	1.51	8.86
(b) Accessions	L	A	L x A	Mean	CV (%)
Days to forage harvest $^{\Phi}$	**	**	**	104.28	0.75
Days to seed harvest	**	**	**	139.53	3.64
Plant height at forage harvest	**	**	**	108.90	13.57
Dry matter yield $^{\Phi}$	**	**	*	5.14	18.16
Crude protein ^{4}	NS	**	NS	21.48	0.68
Crude protein yield	**	**	*	1.10	26.49
Neutral detergent fiber ^{4}	**	**	NS	48.28	10.21
In-vitro dry matter digestibility	**	**	NS	65.23	0.13
Thousand seed weight $^{\Phi}$	NS	**	**	93.78	2.21
Seed yield $^{\Phi}$	**	**	*	1.58	8.48

** = P<0.05; ** = P<0.01; NS =non-significant (P>0.05);* ***L****= Location;* ***S****= Species,* ***L x S****= Location by species interaction;* ***A****= Accessions;* ***L x A****= Location by accessions interaction; $^{\Phi}$ = Log transformation; ^{4} = Square root transformation.*

Forage dry matter yield

Total DM yields were different (P<0.05) at both locations and ranged from 1.39 to 5.84 and 1.99 to 7.62 t ha^{-1}at Holetta and Ginchi respectively (Table 5). *Vicia villosa* gave relatively higher total DM yield followed by *Vicia dasycarpa*, *Vicia atropurpurea*, *Vicia sativa* and *Vicia narbonensis* at Holetta. At Ginchi, *Vicia villosa* produced relatively higher total DM yield followed by *Vicia atropurpurea*, *Vicia dasycarpa*, *Vicia sativa* and *Vicia narbonensis*. Generally, intermediate to late maturing vetch species gave relatively better forage DM yield than early maturing vetch species at both locations. This could be explained in terms of the longer duration of growth which probably enabled the late maturing varieties to take full advantage of the better growing conditions (Ciha, 1983). Fekede (2004) also reported that intermediate to late maturing oats varieties gave comparatively higher forage yield than early maturing. Total DM yield of vetch accessions also showed significant (P<0.05) difference at both locations (Table 8). Muluneh (2006) reported that the yield of vetch species produced at Holetta red soil was more than double compared to the results recorded at Ginchi black soil, because Ginchi was water logged which inhibits soil aeration, nutrient absorption and root growth that made plants stunted and reduced growth rate. Getnet and Ledin (2001) also reported that soil type was found to be the most important factor affecting biomass yield and hence herbage production on the well drained red soil was almost double compared to the black soil. However, in this study comparatively higher biomass yield was obtained at Ginchi black soil than Holetta red soil. Because this studies was carried out on camber-bed which minimized the water logging problem of vertisol that resulted in a relatively higher biomass yield. Experimental finding have also shown that planting chickpea, lentil and faba bean on broad bed and furrow (BBF) resulted in grain yield increments compared to un-drained flat bed conditions (Getachew and Amare, 2004).

Seed yield and thousand seed weight

The seed yield of vetch species differed significantly (P<0.05) at Holetta, but not at Ginchi, which ranged from 0.4 to 0.8 t ha^{-1} with a mean of 0.6 t ha^{-1} at Holetta and from 2.0 to 2.9 t ha^{-1} with a mean of 2.4 t ha^{-1} at Ginchi (Table 6). The highest seed yield was obtained from *Vicia sativa* (0.8 t ha^{-1}) at Holetta and *Vicia narbonensis* (2.9 t ha^{-1}) at Ginchi, whereas the lowest yield was obtained from *Vicia narbonensis* (0.4 t ha^{-1}) at Holetta and *Vicia* *atropurpurea* (2.0 t ha^{-1}) at Ginchi. Thousand seed weight of vetch species also showed a significant (P<0.05) difference at both locations, which ranged from 44.1 to 222.8 g with a mean of 81.7 g at Holetta and from 42.5 to 242.2 g with a mean of 86.3 g at Ginchi (Table 6). The highest thousand seed weight was for *Vicia narbonensis* at both locations, whereas the lowest for *Vicia dasycarpa* and *Vicia villosa* at Holetta and Ginchi respectively. In general, vetch species (*V. narbonensis* and *V. sativa*) which have erect growth habit and early to mature had comparatively higher thousand seed weight than creeping growth habit and intermediate to late maturing vetch species. The seed yield and thousand seed weight also differed significantly (P<0.05) among the accessions of vetch at both locations (Table 8). The difference in thousand seed weight could be due to the inherent variation in seed size complemented with the environmental and soil conditions. This agronomic trait is important for seed rate determination of vetch species. Fekede (2004) also reported that thousand seed weight has got practical significance in estimating seeding rate for each oat variety in order to ensure that equal number of seeds could be sown per unit area.

Table 4. Least square means for days to forage and seed harvest of vetch species grown at Holetta and Ginchi

	Days to forage harvest$^{\Phi}$		Days to seed harvest	
Species	Holetta	Ginchi	Holetta	Ginchi
Vicia sativa	96.1^{c}	107.9^{c}	119.7^{c}	151.3^{b}
Vicia villosa	112.2^{a}	117.4^{b}	149.9^{a}	157.9^{a}
Vicia narbonensis	83.3^{d}	96.8^{d}	113.5^{d}	134.6^{c}
Vicia dasycarpa	105.3^{b}	113.0^{b}	129.7^{b}	156.8^{ab}
Vicia atropurpurea	108.3^{a}	124.7^{a}	135.3^{b}	159.3^{a}
Mean	101.0	112.0	129.6	152.0
CV (%)	0.68	1.01	4.08	4.05
R^2	0.94	0.76	0.90	0.73

Within column means with different superscripts differ significantly (P<0.05); $^{\Phi}$ = Log transformation

Forage chemical compositions and *in-vitro* dry matter digestibility

Chemical compositions at forage harvest

The crude protein (CP) content showed significant (P<0.05) difference among vetch species at both locations (Table 9). The CP content of the species ranged from 18.9 to 25.8% with a mean of 22.4% and from 18.9 to 26.0% with a mean of 22.5% at Holetta and Ginchi respectively. *Vicia dasycarpa* had higher (P<0.05) CP content followed by *Vicia atropurpurea*, *Vicia narbonensis, Vicia villosa* and *Vicia sativa* at both locations. Getnet and Ledin (2001) reported that vetch has a higher CP content compared to many other tropical herbaceous legumes. Most herbaceous legumes have CP content of >15%, a level which is usually required to support lactation and growth, which suggests the adequacy of herbaceous legumes to supplement basal diets of predominately low quality feeds (Norton, 1982). CP content should not be used as the only parameter to be considered during quality evaluation. It is the CP yield, which describes the overall and actual productivity of quality forage. The CP yield of vetch species differed significantly (P<0.05) at both locations (Table 9). *Vicia dasycarpa* had the highest CP yield, while the lowest was recorded from *Vicia narbonensis*. The CP content and CP yield had also significantly different among the accessions of vetches at both locations (Table 10).

The neutral detergent fiber (NDF) content of vetch species differed significantly (P<0.05) at both locations, which ranged from 36.5 to 55.2% with a mean of 48.5% and from 39.5 to 54.3% with a mean of 43.8% at Holetta and Ginchi respectively (Table 11). *Vicia sativa* had higher (P<0.05) NDF content than *Vicia dasycarpa* and *Vicia atropurpurea* at Holetta, whereas *Vicia narbonensis* had the highest (P<0.05) NDF content of all the other vetch species at Ginchi. There were also significant variations (P<0.05) among all the tested accessions at both locations (Table 12). The NDF contents above the critical value of 60% result in decreased voluntary feed intake, feed conversion efficiency and longer rumination time (Meissner *et al*., 1991). However, the NDF content of all the tested vetch species was found below this threshold level which indicates higher digestibility. As stems mature, protein content decreases and carbohydrate content increases and at maturity, stems make up as much as 80% of the total DM and NDF, which generally estimates the percentage of total fiber (cellulose, hemi cellulose and lignin) increases due to increases in xylem tissue (Jung and Engles, 2002). However, a high amount of protein is associated with NDF, increasing the ruminal and total tract digestibility (Mustafa *et al*., 2000).

Table 5. Least square means for plant height (cm) and dry matter yield (t ha^{-1}) at forage harvesting stage of vetch species grown at Holetta and Ginchi

	Plant height at forage harvest$^{\Phi}$		Dry matter yield (t/ha)$^{\Phi}$	
Species	Holetta	Ginchi	Holetta	Ginchi
Vicia sativa	87.1^{b}	102.6^{b}	5.05^{a}	6.79^{a}
Vicia villosa	138.3^{a}	155.2^{a}	5.84^{a}	7.62^{a}
Vicia narbonensis	55.2^{c}	44.3^{c}	1.39^{b}	1.99^{b}
Vicia dasycarpa	151.6^{a}	167.0^{a}	5.46^{a}	6.89^{a}
Vicia atropurpurea	136.9^{a}	185.9^{a}	5.09^{a}	7.13^{a}
Mean	113.8	131.0	4.56	6.09
CV (%)	3.45	4.62	21.12	21.14
R^2	0.87	0.87	0.84	0.74

Within column means with different superscripts differ significantly ($P<0.05$); $^{\Phi}$ = Log transformation

Table 6. Least square means for seed yield (t ha^{-1}) and thousand seed weight (g) of vetch species at Holetta and Ginchi

	Seed yield (t/ha)$^{\Phi}$		Thousand seed weight (g)	
Species	Holetta	Ginchi	Holetta	Ginchi
Vicia sativa	0.8^{a}	2.7	49.4^{b}	54.7^{b}
Vicia villosa	0.7^{a}	2.3	46.2^{b}	42.5^{b}
Vicia narbonensis	0.4^{b}	2.9	222.8^{a}	242.2^{a}
Vicia dasycarpa	0.7^{a}	2.1	44.1^{b}	43.4^{b}
Vicia atropurpurea	0.5^{ab}	2.0	46.1^{b}	48.8^{b}
Mean	0.6	2.4	81.7	86.3
CV (%)	12.42	5.86	24.51	24.99
R^2	0.32	0.12	0.93	0.93

Within column means with different superscripts differ significantly ($P<0.05$); $^{\Phi}$ = Log transformation

Table 7. Average days to forage harvest (days), days to seed harvest (days) and plant height (cm) of different accessions of vetch grown at Holetta and Ginchi

		Days to forage harvest$^{\Phi}$		Days to seed harvest		Plant height (cm)	
Species	Accessions	Holetta	Ginchi	Holetta	Ginchi	Holetta	Ginchi
Vicia sativa	64266	94.0^{e}	103.7^{ef}	119.3^{g}	156.0^{ab}	96.3^{c}	103.3^{e}
Vicia sativa	61904	92.7^{e}	104.0^{ef}	118.7^{g}	155.3^{ab}	89.8^{c}	102.5^{e}
Vicia sativa	61744	97.3^{d}	112.3^{cde}	121.3^{efg}	156.3^{ab}	84.8^{c}	131.1^{cd}
Vicia sativa	61509	97.0^{d}	110.0^{cde}	119.7^{g}	155.3^{b}	85.3^{c}	120.3^{de}
Vicia sativa	61039	99.3^{d}	109.3^{de}	118.7^{g}	138.0^{c}	73.7^{c}	100.3^{e}
Vicia sativa	61212	96.0^{de}	108.0^{de}	120.3^{fg}	147.0^{b}	62.7^{cd}	57.7^{f}
Vicia villosa	2565	113.0^{a}	112.7^{cd}	141.0^{bc}	160.7^{a}	139.1^{ab}	133.1^{cd}
Vicia villosa	2450	111.7^{a}	118.7^{abc}	152.3^{a}	158.7^{a}	123.1^{b}	144.0^{bcd}
Vicia villosa	2424	111.7^{a}	117.3^{abcd}	153.0^{a}	160.3^{a}	148.2^{a}	170.4^{ab}
Vicia villosa	2438	112.0^{a}	116.0^{bcd}	152.0^{a}	156.3^{ab}	119.3^{b}	163.0^{ab}
Vicia villosa	2434	112.0^{a}	126.0^{a}	153.7^{a}	157.7^{a}	160.9^{a}	157.4^{abc}
Vicia villosa	2446	112.7^{a}	113.7^{cd}	147.3^{ab}	153.7^{ab}	139.1^{ab}	158.9^{abc}
Vicia narbonensis	2384	80.7^{g}	98.0^{fg}	114.0^{g}	134.3^{c}	60.7^{de}	47.6^{f}
Vicia narbonensis	2387	82.0^{g}	98.0^{fg}	113.0^{g}	133.7^{c}	48.0^{e}	38.5^{f}
Vicia narbonensis	2376	88.7^{f}	94.3^{g}	113.0^{g}	134.0^{c}	54.8^{de}	45.6^{f}
Vicia narbonensis	2392	80.7^{g}	96.7^{fg}	113.7^{g}	135.0^{c}	53.2^{de}	41.4^{f}
Vicia narbonensis	2380	84.7^{g}	97.0^{fg}	114.0^{g}	135.7^{c}	59.5^{de}	48.3^{f}
Vicia dasycarpa	Namoi	105.3^{c}	115.7^{bcd}	129.3^{def}	161.0^{a}	149.2^{a}	159.2^{abc}
Vicia dasycarpa	Lana	105.3^{c}	110.3^{cde}	130.0^{de}	152.7^{ab}	153.9^{a}	174.8^{a}
Vicia atropurpurea	Atropurpurea	108.3^{bc}	124.7^{ab}	135.3^{cd}	159.3^{a}	136.9^{ab}	185.9^{a}
	Mean	99.3	109.3	129.0	150.1	103.42	114.2
	CV (%)	0.53	0.93	4.15	3.27	13.14	13.42
	R^2	0.97	0.85	0.93	0.87	0.92	0.94

Within column means with different superscripts differ significantly ($P<0.05$); $^{\Phi}$ = Log transformation

Table 8. Average DM yield (tha^{-1}), seed yield ($t\ ha^{-1}$) and thousand seed weight (g) of different accessions of vetch at Holetta and Ginchi

		DM yield (t/ha) $^{\Phi}$		Seed yield (t/ha) $^{\Phi}$		1000 seed weight (g) $^{\Phi}$	
Species	Accessions	Holetta	Ginchi	Holetta	Ginchi	Holetta	Ginchi
Vicia sativa	64266	5.65^{ab}	6.52^{ab}	0.6^{abcd}	2.8^{abcd}	54.7^{d}	61.3^{f}
Vicia sativa	61904	5.96^{ab}	6.13^{ab}	1.0^{a}	2.8^{abcd}	54.3^{d}	60.2^{fg}
Vicia sativa	61744	5.25^{ab}	9.04^{a}	0.6^{abcd}	2.9^{abcd}	46.0^{def}	56.5^{g}
Vicia sativa	61509	5.10^{ab}	7.79^{ab}	0.9^{a}	3.1^{abc}	54.7^{d}	67.7^{e}
Vicia sativa	61039	3.76^{ab}	8.38^{ab}	0.7^{abc}	1.4^{e}	37.9^{f}	26.4^{k}
Vicia sativa	61212	4.57^{ab}	2.84^{c}	0.8^{ab}	3.2^{ab}	48.8^{de}	56.0^{g}
Vicia villosa	2565	5.24^{ab}	5.44^{ab}	0.8^{ab}	2.8^{abcd}	46.2^{def}	42.6^{i}
Vicia villosa	2450	4.68^{ab}	7.73^{ab}	0.7^{abc}	2.3^{bcde}	46.5^{de}	39.1^{j}
Vicia villosa	2424	7.48^{a}	8.66^{ab}	0.9^{a}	2.4^{bcd}	47.0^{de}	41.7^{ij}
Vicia villosa	2438	4.70^{ab}	8.60^{ab}	0.5^{abcd}	2.1^{bcde}	46.2^{def}	42.4^{i}
Vicia villosa	2434	6.98^{a}	8.11^{ab}	0.8^{ab}	2.3^{bcde}	46.6^{de}	44.0^{i}
Vicia villosa	2446	5.96^{ab}	7.16^{ab}	0.6^{abcd}	1.9^{cde}	44.8^{def}	44.9^{i}
Vicia narbonensis	2384	1.46^{c}	2.21^{c}	0.5^{abcd}	3.1^{abc}	199.8^{bc}	243.9^{c}
Vicia narbonensis	2387	1.49^{c}	1.87^{c}	0.3^{cd}	2.2^{bcde}	248.4^{ab}	201.2^{d}
Vicia narbonensis	2376	1.06^{c}	1.76^{c}	0.3^{cd}	3.0^{abcd}	258.0^{a}	301.6^{a}
Vicia narbonensis	2392	1.47^{c}	1.99^{c}	0.4^{bcd}	1.9^{cde}	177.3^{c}	192.9^{d}
Vicia narbonensis	2380	1.44^{c}	2.15^{c}	0.6^{abcd}	4.2^{a}	230.6^{ab}	271.7^{b}
Vicia dasycarpa	Namoi	4.83^{ab}	7.30^{ab}	0.7^{abc}	2.2^{bcde}	45.7^{def}	44.1^{i}
Vicia dasycarpa	Lana	6.09^{ab}	6.48^{ab}	0.8^{ab}	1.9^{cde}	42.4^{ef}	44.6^{i}
Vicia atropurpurea	Atropurpurea	5.09^{ab}	7.14^{ab}	0.5^{abcd}	2.0^{bcde}	46.1^{def}	48.8^{h}
	Mean	4.41	5.87	0.6	2.5	91.1	96.5
	CV (%)	20.05	16.89	12.53	4.75	2.96	1.03
	R^2	0.90	0.88	0.51	0.58	0.98	1.00

Within column means with different superscripts differ significantly ($P<0.05$); $^{\Phi}$ = Log transformation

In-vitro dry matter digestibility at forage harvest

The *in-vitro* dry matter digestibility (IVDMD) of vetch species was significantly different at both locations (Table 11). IVDMD ranged from 60.47 to 73.39% with a mean of 66.47% and from 60.33 to 73.22% with a mean of 66.31% at Holetta and Ginchi respectively. At both locations, IVDMD of *Vicia dasycarpa* was the highest ($P<0.05$), while *Vicia sativa* was the lowest. The IVDMD values greater than 65% indicates good feeding value (Mugeriw *et al*., 1973) and values below this threshold level result in reduced intake due to lowered digestibility. The IVDMD values observed in this study were above this threshold level for all vetch species except *Vicia sativa* at both locations, which may implicate higher voluntary intake and digestibility of vetch species. This result is supported by the findings of Getnet and Ledin (2001).

Table 9. Least square means for crude protein (CP) on (%) DM basis and CP yield (t ha^{-1}) of vetch species at Holetta and Ginchi

	CP %^{4}		CP yield (t/ha)^4	
Species	Holetta	Ginchi	Holetta	Ginchi
Vicia sativa	18.9^{e}	18.9^{e}	1.0^{b}	1.3^{b}
Vicia villosa	21.4^{d}	21.6^{d}	1.3^{a}	1.6^{ab}
Vicia narbonensis	22.4^{c}	22.4^{c}	0.3^{c}	0.5^{c}
Vicia dasycarpa	25.8^{a}	26.0^{a}	1.4^{a}	1.8^{a}
Vicia atropurpurea	23.4^{b}	23.6^{b}	1.2^{ab}	1.7^{a}
Mean	22.4	22.5	1.0	1.4
CV (%)	0.61	0.95	28.48	30.69
R^2	0.99	0.97	0.71	0.66

Within column means with different superscripts differ significantly ($P<0.05$); ^{4} = Square root transformation

Table 10. Average crude protein (CP) content on (%) DM basis and CP yield (t ha^{-1}) of different accessions of vetch at Holetta and Ginchi

		CP (%)^4		CP yield (t/ha)	
Species	Accessions	Holetta	Ginchi	Holetta	Ginchi
Vicia sativa	64266	18.8^{gh}	19.1^{e}	1.1^{cde}	1.2^{b}
Vicia sativa	61904	19.0^{g}	19.1^{e}	1.1^{cde}	1.2^{b}
Vicia sativa	61744	19.0^{g}	18.9^{e}	1.0^{de}	1.7^{ab}
Vicia sativa	61509	19.0^{g}	18.9^{e}	1.0^{de}	1.5^{ab}
Vicia sativa	61039	18.6^{h}	18.2^{f}	0.7^{ef}	1.5^{ab}
Vicia sativa	61212	19.0^{g}	19.1^{e}	0.9^{de}	0.6^{c}
Vicia villosa	2565	21.3^{f}	21.5^{d}	1.2^{bcde}	1.2^{b}
Vicia villosa	2450	21.9^{e}	22.3^{c}	1.0^{de}	1.7^{ab}
Vicia villosa	2424	21.4^{f}	21.4^{d}	1.6^{a}	1.9^{a}
Vicia villosa	2438	21.4^{f}	21.5^{d}	1.0^{de}	1.9^{a}
Vicia villosa	2434	21.4^{f}	21.2^{d}	1.5^{abc}	1.7^{ab}
Vicia villosa	2446	21.4^{f}	21.5^{d}	1.3^{abcd}	1.5^{ab}
Vicia narbonensis	2384	22.5^{cd}	22.3^{c}	0.3^{fg}	0.5^{c}
Vicia narbonensis	2387	22.6^{c}	22.4^{c}	0.3^{fg}	0.4^{c}
Vicia narbonensis	2376	22.3^{cde}	22.3^{c}	0.2^{g}	0.4^{c}
Vicia narbonensis	2392	22.5^{cd}	22.5^{c}	0.3^{fg}	0.5^{c}
Vicia narbonensis	2380	22.1^{de}	22.2^{c}	0.3^{fg}	0.5^{c}
Vicia dasycarpa	Namoi	25.8^{a}	26.0^{a}	1.3^{abcd}	1.9^{a}
Vicia dasycarpa	Lana	25.8^{a}	26.0^{a}	1.6^{a}	1.7^{ab}
Vicia atropurpurea	Atropurpurea	23.4^{b}	23.6^{b}	1.2^{abcd}	1.7^{ab}
	Mean	21.5	21.5	0.9	1.3
	CV (%)	0.55	0.80	26.30	26.59
	R^2	0.99	0.98	0.82	0.81

Within column means with different superscripts differ significantly ($P<0.05$); ^{4} = Square root transformation

On the other hand, accessions of vetch showed significant (P<0.05) difference in apparent digestibility at both locations (Table 12). It was generally observed that early maturing vetch accessions had lower IVDMD compared to intermediate to late maturity vetch accessions. This could be due to the presence of higher fiber and cell wall constituents, and lower CP content in the early maturing vetch accessions than the intermediate to late maturing accessions. IVDMD of any forage crop varied with harvesting stage, fiber and cell wall constituents (Mustafa *et al*., 2000); proportions of morphological fractions (Fekede, 2004); soil, plant species and climate (Getnet and Ledin 2001).

Table 11. Least square means for neutral detergent fiber (NDF) and *in-vitro* dry matter digestibility (IVDMD) on (%) DM basis of vetch species at Holetta and Ginchi

	NDF %[4]		IVDMD (%)	
Species	Holetta	Ginchi	Holetta	Ginchi
Vicia sativa	55.2[a]	39.5[b]	60.47[e]	60.33[e]
Vicia villosa	51.6[ab]	43.9[b]	66.41[c]	66.21[c]
Vicia narbonensis	54.4[a]	54.3[a]	66.54[b]	66.37[b]
Vicia dasycarpa	44.7[bc]	39.7[b]	73.39[a]	73.22[a]
Vicia atropurpurea	36.5[c]	41.7[b]	65.56[d]	65.45[d]
Mean	48.5	43.8	66.47	66.31
CV (%)	7.79	12.35	0.15	0.14
R^2	0.42	0.24	1.00	1.00

Within column means with different superscripts differ significantly (P<0.05); [4] = Square root transformation

Table 12. Average neutral detergent fiber (NDF) and *in-vitro* dry matter digestibility (IVDMD) on (%) DM basis of different accessions of vetch at Holetta and Ginchi

		NDF %[4]		IVDMD (%)	
Species	Accessions	Holetta	Ginchi	Holetta	Ginchi
Vicia sativa	64266	50.1[abc]	37.0[bc]	60.49[fg]	60.33[hi]
Vicia sativa	61904	60.4[a]	35.3[c]	60.44[fg]	60.29[i]
Vicia sativa	61744	53.8[abc]	42.2[bc]	60.49[fg]	60.30[hi]
Vicia sativa	61509	57.2[ab]	42.5[abc]	60.48[fg]	60.42[gh]
Vicia sativa	61039	60.4[a]	45.4[abc]	60.56[f]	60.50[g]
Vicia sativa	61212	49.0[abcd]	35.8[c]	60.38[g]	60.16[j]
Vicia villosa	2565	49.5[abcd]	46.2[abc]	66.37[cd]	66.17[e]
Vicia villosa	2450	55.2[ab]	56.7[abc]	66.44[cd]	66.18[e]
Vicia villosa	2424	53.5[abc]	41.3[bc]	66.44[cd]	66.29[cde]
Vicia villosa	2438	51.3[abc]	37.5[bc]	66.34[d]	66.19[de]
Vicia villosa	2434	44.6[bcd]	39.2[bc]	66.39[cd]	66.19[de]
Vicia villosa	2446	55.7[ab]	42.6[abc]	66.46[cd]	66.23[de]
Vicia narbonensis	2384	51.0[abc]	46.8[abc]	66.50[bcd]	66.38[bc]
Vicia narbonensis	2387	55.7[ab]	64.8[a]	66.50[bcd]	66.36[bc]
Vicia narbonensis	2376	60.2[a]	46.4[abc]	66.54[bc]	66.38[bc]
Vicia narbonensis	2392	50.7[abc]	58.3[ab]	66.51[bcd]	66.43[b]
Vicia narbonensis	2380	54.2[abc]	55.2[abc]	66.64[b]	66.31[bcd]
Vicia dasycarpa	Namoi	39.9[cd]	34.7[c]	73.31[a]	73.18[a]
Vicia dasycarpa	Lana	49.5[abcd]	44.7[abc]	73.46[a]	73.25[a]
Vicia atropurpurea	Atropurpurea	36.5[d]	41.7[bc]	65.56[e]	65.45[f]
	Mean	51.9	44.6	65.31	65.15
	CV (%)	7.76	12.28	0.14	0.11
	R^2	0.59	0.46	1.00	1.00

Within column means with different superscripts differ significantly (P<0.05); [4] = Square root transformation

Relationships between agro-morphological traits

The linear correlation coefficients between observed agro-morphological characters are shown in Table 13. Days to forage harvest showed a strong (P<0.001) positive correlation with days to seed harvest (r= 0.95), plant height at forage harvest (r= 0.94), forage DM yield (r= 0.85), but negatively correlated (P<0.001) with thousand seed weight (r= -0.82). It was also negatively correlated (P>0.05) with seed yield (r= -0.26). Fekede (2004) also reported that days to maturity of forage correlated positively with plant height, herbage yield, but negatively correlated with seed yield and thousand seed weight of oats varieties. Generally, early maturing vetch accessions had shorter plant height, higher seed yield and thousand seed weight, lower DM yield than late maturing accessions. Plant height at forage harvest showed a significant (P<0.001) positive correlation with forage DM yield (r= 0.86). It was negatively (P<0.001) correlated with thousand seed weight (r= -0.79), and seed yield (r= -0.26; P>0.05). Fekede (2004) also reported that plant height at forage harvest was positively and significantly correlated with herbage yield, whereas it was negatively correlated with grain yield and thousand seed weight of oats varieties. Getnet *et al*., (2003) also reported that taller and late maturing oats varieties had higher forage yield but lower grain yield.

Table 13. Pearson's correlation coefficients between agro-morphological traits of accessions of different vetch species

Parameters	DFH	DSH	PHFH	DMY	TSW
DSH	0.95***				
PHFH	0.94***	0.92***			
DMY	0.85***	0.83***	0.86***		
TSW	-0.82***	-0.76**	-0.79***	-0.91***	
SY	-0.26	-0.16	-0.26	-0.16	0.21

DFH= Days to forage harvest; **DSH**=Days to seed harvest; **PHFH** =Plant height at forage harvest; **DMY**= Dry matter yield; **TSW**= Thousand seed weight; **SY**= Seed yield

Relationships between nutritional traits

The linear correlation coefficients between nutritional characters are shown in Table 14. The CP content showed a significant (P<0.001) positive correlation with IVDMD (r= 0.96), but non-significant positive correlation with CP yield (r= 0.13). It was not significantly and inversely correlated with NDF content (r= -0.11). The NDF content had very weak and non significant negative correlation with IVDMD (r= -0.09). According to Tessema *et al*., (2002), significant but negative correlations were found between IVDMD and cell wall components, and IVDMD and CP were significantly and positively correlated in Napier grass. Tessema *et al*., (2002) also reported that CP showed high positive correlations with IVDMD, whereas NDF showed negative correlations with IVDMD in Napier grass harvested at different heights.

Table 14. Pearson's correlation coefficients between nutritional parameters of accessions of different vetch species

Parameters	CP	CPY	NDF
CPY	0.13		
NDF	-0.11	-0.59**	
IVDMD	0.96***	0.16	-0.09

CP= Crude protein; **CPY**= Crude protein yield;
NDF= Neutral detergent fiber; **IVDMD**= *In-vitro* dry matter digestibility

Relationships between agro-morphological and nutritional traits

The linear correlation coefficients between agro-morphological and nutritional characters are shown in Table 15. The CP content was positively correlated with days to forage harvest (r= 0.09), plant height at forage harvest (r= 0.28), and forage DM yield (r= 0.19). It was also negatively correlated with seed yield (r= -0.30). Generally, intermediate to late maturing accessions of vetch had comparatively higher CP content than early maturing ones. The CP yield showed a significant (P<0.001) positive correlation with days to forage harvest (r= 0.81), plant height at forage harvest (r= 0.84), and forage DM yield (r= 0.83). On the other hand, CP yield was negatively correlated with seed yield (r= -0.27). Generally, early maturing accessions had comparatively lower CP yield than intermediate to late maturing ones. The NDF content showed a significant positive correlation with seed yield (r= 0.05). It had a significant (P<0.05) negative correlation with days to forage harvest (r= -0.55), plant height at forage harvest (r= -0.62), and forage DM yield (r= -0.53). The IVDMD had a positive correlation with days to forage harvest (r= 0.17), plant height at forage harvest (r= 0.31), and forage DM yield (r= 0.10), but negatively correlated with seed yield (r= -0.31).

Table 15. Pearson's correlation coefficients between agro-morphological and nutritional parameters of accessions of different vetch species

	Nutritional qualities			
Agro-morphological parameters	CP	CPY	NDF	IVDMD
Days to forage harvest	0.09	0.81***	-0.55**	0.17
Plant height at forage harvest	0.28	0.84***	-0.62**	0.35
Dry matter yield	0.19	0.83***	-0.53**	0.10
Seed yield	-0.30	-0.27	0.05	-0.31

CP= Crude protein; **CPY**= Crude protein yield; **NDF**= Neutral detergent fiber;
IVDMD= In-vitro dry matter digestibility

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