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Evaluation of vetch species for yield, yield components and herbage quality in the central highlands of Ethiopia

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Five vetch species were evaluated for their morphological, agronomical and nutritional differences at Holetta and Ginchi in the central highlands of Ethiopia during 2009 cropping season. The experiment was conducted in randomized complete block design with three replications. At sowing, 100 kg DAP/ha was applied for all treatments. Data were collected and analyzed using the general linear model procedures of SAS, and Duncan multiple range test was used for mean comparison. Most measured parameters showed significant (P<0.05) difference among the tested vetch species at both locations. *Vicia narbonensis* and *V. sativa* had an erect growth habit, short plant height and early maturity for forage and seed yields, while *V. dasycarpa*, *V. villosa* and *V. atropurpurea* had creeping growth habit, tall plant height and intermediate to late maturity for both forage and seed yields. The difference between late and early maturing species for forage harvest was 25.0 days at Holetta and 27.9 days at Ginchi. The difference between taller and shorter plant height at forage harvest was 96.3 cm at Holetta and 141.6 cm at Ginchi. Early maturing species had higher biomass production rate and the difference between higher and lower was 37.5 kg/ha/day at Holetta and 47.8 kg/ha/day at Ginchi. Taller vetch species gave better forage DM yield at forage harvest and the difference between higher and lower was 4.45 t/ha at Holetta and 5.63 t/ha at Ginchi. Early maturing species had shorter grain filling period and the difference between higher and lower was 25.5 and 9.8 days, and higher grain sink filling rate with the difference of 9.2 and 15.0 kg/ha/day at Holetta and Ginchi respectively. Early maturing species had lower number of pods per plant and the difference between higher and lower was 77.7 and 128.5, but higher pod length 2.7 and 2.6 cm, number of seeds per pod 2.7 and 2.6, thousand seed weight 178.8 and 199.8 g and seed yield 0.4 and 0.8 t/ha at Holetta and Ginchi respectively. Creeping species (*V. dasycarpa*) had comparatively better ash (10.4 and 9.5%), CP (25.8 and 26.0%) and IVDMD (73.4 and 73.2%) at Holetta and Ginchi respectively, but lower fiber (NDF) content than erect species. Generally, vetch species had a great variation in morphological, agronomical and nutritional parameters.

Key words: agronomic performance, forage yield, herbage quality, seed yield, vetch species

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INTRODUCTION

The Ethiopian highlands above 1500 masl receiving more than 700 mm annual rainfall and have a mean daily temperature of less than 20^{o}C (Zinash et al., 2001). About 88% of the human population, 70% of cattle and sheep, 30% of goats and 80% of equines are found in this region (Saleem and Tedla, 1995; Alemayehu, 2004). The central highland of Ethiopia is characterized by crop-livestock mixed farming systems. Livestock is an integral component for most of the agricultural activities in the country. The share of livestock sub sector in the national economy is estimated to be 12-16% to the total Gross Domestic Product (GDP), 30-35% to the agricultural GDP (LMA, 1999; 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 in the highlands, they are faced with multifaceted problems in the production system, among which the major one is the quantitative and qualitative inadequacy of feed supply. Indeed, insufficient and poor quality feed, particularly during the dry periods was reported to be one of the most important constraints to Ethiopian livestock feeding systems (Anderson, 1987). Similar studies (Seyoum and Zinash 1995; Zinash et al., 1995) reported feed resources to be the major bottleneck to livestock production in the highlands of Ethiopia, where natural pastures and crop residues are the major sources of feed. Saleem and Tedla (1995) also reiterated that herbage from natural pasture are usually inadequate quantitatively and qualitatively to support reasonable livestock production. The natural pasture is estimated to contribute about 50 to 60 % of the total feed supply, mainly in the upper highlands. But natural pasture is poorly managed throughout the country. Overstocking and overgrazing have resulted in the disappearance of valuable species, spread of unpalatable species and land degradation (Lulseged, 1985).

Ethiopia has an immense ecological diversity and a huge wealth of biological resources. The complex topography coupled with environmental heterogeneity offers suitable environments for a wide range of life forms. Introduction of cultivated forage legumes such as vetch in the farming system is a key factor to solve feed shortage. Legumes forage like vetch is rich sources of N for livestock with cheaper prices compared to concentrates especially in developing countries (Seyoum, 1994). Getnet and Inger (2001) also found that vetch has a higher CP content compared to many other tropical herbaceous legumes. Vetch is annual forage legumes widely adapted to the highlands of Ethiopia (IAR, 1986). 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 an acid pH of 5.5-6 (IAR, 1980). Vetch species have different characteristics in terms of growth habit, life cycle and climatic adaptation. These characteristics are very important to determine their production, utilization and the various management practices. Information on days to maturity, plant height, growth habit and other characteristics of vetch species are vital for further research and development activities. Previous evaluations of vetch species were done mainly on environmental adaptation and biomass yield but there is no wide assessment on different vetch species with respect to growth features, forage and seed productivity and forage quality. Accordingly, there is a need to evaluate vetch species for basic quantitative and qualitative traits to address the feed demand of mixed farming systems. Therefore, this study was designed to evaluate agronomical, morphological and nutritional attributes of vetch species under the two soil types and climatic conditions in the central highland areas of Ethiopia.

MATERIALS AND METHODS

Description of the study sites

The experiment was conducted at Holetta and Ginchi sub center during the main cropping season of 2009 under rain fed condition. Holetta 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 and is characterized with the long term (30 years) average annual rainfall of 1055.0 mm, average relative humidity of 60.6%, and average maximum and minimum air temperatures of 22.2°c and 6.1°c respectively. The rainfall is bimodal and about 70% of the precipitation falls in the period from June to September, while the remaining thirty percent falls in the period from March to May (EIAR, 2005). The soil type of the area is predominantly red nitosol, which is characterized by an average organic matter content of 1.8%, total nitrogen 0.17%, pH 5.24, and available phosphorus 4.55 ppm (Gemechu, 2007). Ginchi sub center is located at 75 km west of Addis Ababa in the same road 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 characterized with the long term (30 years) average annual rainfall of 1095.0 mm, average relative humidity of 58.2%, and average maximum and minimum air temperatures of 24.6°c and 8.4°c respectively. The site has a bimodal rainfall pattern, with the main rain from June to September and short rain from March to May (EIAR, 2005). The soil of the area is predominately black clay vertisol with organic matter content of 1.3%, total nitrogen 0.13%, pH 6.5 and available phosphorus 16.5 ppm (Getachew et al., 2007).

Experimental treatments and design

The study was executed using five vetch species viz *Vicia sativa*, *Vicia villosa*, *Vicia narbonensis*, *Vicia dasycarpa* and *Vicia atropurpurea*. Among these, the first three vetch species were introduced from International Center for Agricultural Research in the Dry Areas (ICARDA) while the remaining two species were introduced from Australia. The experimental fields were prepared following the recommended tillage practice and a fine seed bed was used at planting. At Ginchi site, sowing was done on Camber-beds to improve drainage and reduce water-logging problems of vertisol. The experiment was conducted on a Randomized Complete Block Design (RCBD) with three replications. Seeds were drilled in rows of 30 cm on a plot size of 2.4 m x 4 m= 9.6 m^2, which consisted of 8 rows. Based on experimental design, each treatment was assigned randomly to the experimental units within a block. The species were sown according to their recommended seeding rates: 25 kg/ha for *Vicia villosa*, *Vicia dasycarpa* and *Vicia atropurpurea*; 30 kg/ha for *Vicia sativa* and 75 kg/ha for *Vicia narbonensis*. At sowing, 100 kg/ha diamonium phosphate (DAP) fertilizer was uniformly applied for all treatments at both locations. The two rows next to the guard rows were used for determination of number of pods per plant, pod length per plant and number of seeds per pod. The two rows prior to the inner two rows were used to evaluate proportion of morphological fractions, forage and morphological fraction yields and forage quality. The remaining two rows were used for seed yield determination. The first hand weeding was made thirty days after crop emergence and the second weeding was done thirty days after the first weeding. Generally, maximum cares were taken in the experimental plots to reduce the possible yield limiting factors which could affect the performance of vetch species.

Agronomic data collection

Days to 50% flowering and days to seed maturity were counted from days to emergence to the date when plants reach the respective growth stages. Plant height was measured from ground to the tip of the plant at the time of 50% flowering. Six plants were randomly selected from each plot and their stretched and un-stretched heights were taken at forage harvesting. For determination of biomass yield, vetch species were harvested at 50% flowering. Weight of the total fresh biomass yield was recorded from each plot in the field and the estimated 1 kg of sample was taken from each plot to the laboratory. Half of the sample taken from each plot was weighed to know the sample fresh weight using sensitive table balance, oven dried for 72 hours at a temperature of 65 ^oc. The oven dried samples were weighed to determine dry matter yield, and then used for laboratory analysis to determine chemical composition and *in-vitro* dry matter digestibility. The remaining half of the sample taken from each plot was weighed to know the sample fresh weight and manually fractionated in to leaf, stem, and green pod and flower. The morphological parts were separately weighed to know their sample fresh weight, oven dried for 72 hours at a temperature of 65 ^oc and separately weighed to estimate the proportions of these morphological parts. Proportion of each morphological fraction in percent was then computed as the ratio of each dry biomass fraction to total dry biomass yield and then multiplied by 100. Leaf, stem, and green pod and flower yields then estimated by multiplying each proportion of morphological fraction by total dry biomass yield and then divided by 100. Biomass production rate was computed by dividing the above ground biomass yield to number of days to 50% flowering. Grain filling period (GFP) and grain sink filling rate (GSFR) were also used to determine seed yield related performance. Accordingly, number of days between days for flower initiation and days to seed maturity is known as GFP, while GSFR is calculated as the ratio of grain yield to number of days from flower initiation to seed maturity. Six plants were randomly taken and uprooted at seed setting stage from each plot for determination of number of pods per plant. Six pods were then randomly taken from uprooted plants to measure pod length and the number of seeds per pod was counted. Seed samples were taken and oven dried at 100°c for 48 hours to adjust moisture content of 10%, a recommended percentage level for legumes (Biru, 1979). Seed yield and thousand seed weight were then calculated at 10% moisture content.

Chemical analysis and *in vitro* dry matter digestibility

The oven dried samples were ground to pass through a 1 mm sieve size for laboratory analysis. Before scanning, the samples were dried at 60 ^oc overnight in an oven to standardize the moisture and then 3 g of each sample was scanned by the Near Infra Red Spectroscopy (NIRS) with an 8 nm step. The samples were analyzed in % DM basis for ash, crude protein (CP), neutral detergent fiber (NDF), and *in-vitro* dry matter digestibility (IVDMD) using a calibrated NIRS (Foss 5000 apparatus and Win ISI II software). This is one of the recent techniques that uses a source of producing light of known wavelength pattern (usually 800- 2500 nm) and that enables to obtain a complete picture of the organic composition of the analyzed substance/materials (Van Kempen, 2001). It is now recognized as a valuable tool in the accurate determination of the chemical composition, digestibility parameters and gas production parameters of a wide range of forages (Givens et al., 1997; Herrero et al., 1997; Adesogan et al., 1998; Park et al., 1998).

Statistical analysis

Analysis of variance (ANOVA) procedures of SAS general linear model (GLM) was used to compare treatment means (SAS, 2002). The F- test for homogeneity of variance was carried and its value was computed as the ratio of the two error mean squares; the larger error mean square in the numerator and the smaller error mean square in the denominator (Gomez and Gomez, 1984). According to Gomez and Gomez (1984), the error variances could be considered homogeneous when the error mean square ratio was not greater than the tabulated F- value. Different transformation methods viz Logarithmic, square root and arcsine (angular) were used for data which couldn't exhibit homogeneity of variance for agro-morphological and quality parameters 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 data was analyzed using the following model: $Y_{ijk} = \mu + T_i + L_j + B_{k(j)} + e_{ijk}$ 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, $B_{k\,(j)}$ = effect of block k in location j, e_{ijk} = random error effect of treatment i in block k of location j

RESULSTS AND DISCUSSION

Days to forage harvest

Days to forage and seed harvest for tested vetch species varied across the sites. Though Ginchi site is relatively warmer than Holetta, early maturity for forage and seed were recorded at Holetta than Ginchi. This could be due to high and extended rainfall at Ginchi during the cropping season that encouraged vegetative growth and delayed forage and seed harvesting stages. On average about 10 and 20 more days were required to harvest forage and seed yield respectively at Ginchi compared to Holetta. Days to forage harvest for vetch species showed significant (P<0.05) difference at both locations (Table 1). 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 harvesting at Holetta and Ginchi respectively. *Vicia narbonensis* was significantly early (P<0.05), while *Vicia atropurpurea* 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 vetch species. Variation in forage maturity is an important agronomic trait to select companion crops for maximum production. Getnet et al., (2003) also reported that days to maturity had an advantage of selecting companion or mixture crops that best synchronizes to the days to maturity for better compatibility and forage yield. Late maturing varieties stay green for longer period of time and farmers get green feed for their livestock for longer period. On the other hand, early maturing varieties could be sown in short rains to feed the livestock during 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). According to Fekede (2004), early maturing 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. He also reported that 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.

Days to seed harvest

The days to seed maturity of species also showed similar trend to days to maturity for forage at both locations (Table 1). *Vicia narbonensis* showed significantly earlier (P<0.05) than the remaining species at both locations. On the other extreme, *Vicia villosa* was significantly late (P<0.05) for seed harvest at Holetta but not significantly late with *Vicia dasycarpa* and *Vicia atropurpurea* at Ginchi. According to Getnet et al., (2003) *Vicia narbonensis* and *Vicia sativa* are early maturing; *Vicia dasycarpa* and *Vicia atropurpurea* are intermediate; and *Vicia villosa* is late maturing species recommended and utilized in the highlands of Ethiopia. Phenology (earliness and lateness) of vetch species has a great effect on seed yield productivity. For seed purpose, early maturing species should be grown at Holetta, whereas early and late maturing specie at Ginchi, because seed yield reduction by frost is low due to relatively warm climatic condition. *Vicia narbonensis*, *Vicia sativa* and *Vicia dasycarpa* should be grown for seed production due to earliness to escape frost months, whereas late maturing species like *Vicia villosa* and *Vicia atropurpurea* should not be advisable to grow for seed purpose at Holetta. However, all vetch species should be grown for seed purpose at Ginchi. Seed shattering is the common characteristics of most annual forage legumes. The pods on the upper part of the plant are still at grain filling period, while those of the lower pods have reached maturity due to indeterminate growth nature of vetch species which makes seed harvesting stage quite difficult. Hence, seed loss due to shattering problem is very high in the field unless a frequent follow-up is not taken especially at grain filling period. Farmers in the highlands of Ethiopia are reluctant to plant vetch on their field due to seed shattering problem, because the shattered seeds can grow during the onset of rain and becomes a weed for the succeeding crop. However, harvesting of such legumes at optimum maturity period can reduce the loss of seed as well as the weed effect on the succeeding crop. Generally, variation in seed maturity period of the vetch species over the testing sites need

Table 1: Least square means for days to forage and seed harvests of vetch species grown at Holetta and Ginchi.

	Days to forage harvest		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**

Means followed by a common superscript letters with in a column are not significantly different from each other at P<0.05.

Table 2: Least square means for stretched and un-stretched height (cm) of vetch species at forage harvesting at Holetta and Ginchi.

	Stretched height		Un-stretched height	
Species	Holetta	Ginchi	Holetta	Ginchi
Vicia sativa	87.1^{b}	102.6^{b}	62.2^{a}	51.9^{c}
Vicia villosa	138.3^{a}	155.2^{a}	62.9^{a}	61.8^{b}
Vicia narbonensis	55.2^{c}	44.3^{c}	49.3^{b}	37.2^{d}
Vicia dasycarpa	151.6^{a}	167.0^{a}	63.2^{a}	71.3^{a}
Vicia atropurpurea	136.9^{a}	185.9^{a}	62.2^{a}	66.5^{ab}
Mean	**113.8**	**131.0**	**60.0**	**57.7**
CV (%)	**3.45**	**4.62**	**12.94**	**13.64**
R^2	**0.87**	**0.87**	**0.46**	**0.73**

Means followed by a common superscript letters with in a column are not significantly different from each other at P<0.05.

careful selection of the legumes to be sown in a particular soils and climatic conditions.

Plant height at forage harvest

The tested vetch species showed significant variation (P<0.05) in plant height (stretched and un-stretched) at forage harvesting stage (Table 2). In addition to genetic variability, soil fertility and environmental conditions could also contribute to the difference in height. The average stretched plant height was higher at Ginchi compared to Holetta, which could be attributed to higher and extended rainfall and favorable growing conditions. The previous results on plant height also showed that the tallest plant height was obtained at Ginchi than Holetta. *Vicia dasycarpa*, *Vicia villosa* and *Vicia atropurpurea* have creeping or climbing growth habit, whereas *Vicia narbonensis* and *Vicia sativa* have erect growth habit. Hence, due to these differences in growth habit, two types of plant heights (stretched and un-stretched) were taken to evaluate their height performance at both locations. The tallest stretched 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 narbonensis* was the shortest at both testing sites. There are different methods to integrate forage legumes with food crops especially with cereals. During integration, plant height as well as growth habit should be considered, because it has an impact on compatibility. Studies at Holetta showed that shorter oats varieties were more compatible with vetch than taller varieties regardless of other features such as soil fertility status and fertilizer application (Getnet, 1999). Though *Vicia sativa* has also an erect growth habit, creeping growth habit was observed due to good soil fertility of the experimental plots and favorable environmental conditions during experimental period. However, unlike the creeping species, the difference between stretched and un-stretched plant height for *Vicia sativa* was quite low. Getnet et al., (2003) also reported that *Vicia sativa* has an erect growth habit but lodges on fertile soils and has a tendency of creeping. 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 reduced 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.

Proportions of morphological fractions at forage harvest

Proportions of morphological fractions including leaf, stem, and green pod and flower in the dry matter basis of vetch species were also affected by genetic and environmental conditions at forage harvesting stage. Mean proportion of leaf was higher but stem and green pod and flower were relatively lower at Ginchi than Holetta. Getnet and Ledin (2001) also reported that oats had a higher proportion of stems on red soil and had more leaves on black soil. In this study, higher leaf to stem ratio was obtained at Ginchi than Holetta, this might be due to vigorous growth and higher leaf area expansion than stem growth at Ginchi when compared with Holetta. The average proportions of leaf, stem, and green pod and flower were significantly ($P<0.05$) different among vetch species (Table 3). The result revealed that proportion of leaf was in the range of 23.0 to 36.7% at Holetta and 23.5 to 36.7% at Ginchi at forage harvest. The highest leaf proportion was obtained from *Vicia narbonensis* followed by *Vicia sativa*, *Vicia atropurpurea*, *Vicia villosa* and *Vicia dasycarpa* at both locations. Though *Vicia narbonensis* gave the highest leaf proportion due to its low branching performance and broad leaf type, it didn't give the highest total leaf DM yield per unit area. This might be related to its low total forage DM productivity per unit area. Leaves contain larger proportions of non-lignified tissues; will have faster rates of cell wall digestion than stems, and legumes leaves will be much more quickly digested than grass leaves because of the differences in tissue lignifications of these forages (Jung and Engels, 2002). Generally, leaf proportion has a great impact on forage quality and hence should be considered during selection of the forage crop. McDonald et al., (1995) reported that leafy varieties usually have high total digestible nutrient, crude protein and intake by animals.

The highest stem proportion at forage harvest was obtained from *Vicia dasycarpa* at Holetta and *Vicia atropurpurea* at Ginchi, while, *Vicia narbonensis* gave the lowest stem proportion at both locations. This variation in stem proportion could be due to the difference in branching or tillering performance of vetch species at forage harvest. Generally, species with low branching types had lower stem proportion and vice versa. Getnet et al., (2002) reported that higher stem proportion of oats hay were refused by animals and hence varieties with high proportion of leaf more nutritious than varieties with high proportion of stem. Green pod and flower proportion for vetch species showed significant ($P<0.05$) difference at Holetta but not at Ginchi (Table 3). Proportion of green pod and flower was lower compared with the others morphological fractions such as leaf and stem at forage harvest. Variation in green pod and flower proportion at each testing site could be due to variation in genetic traits such as stage of maturity and branching/tillering performance. Phenology (earliness and lateness) has a great effect on green pod and flower proportion. In general early maturing vetch species produced large number of green pod and flower than late maturing species at forage harvesting stage. Among the species, *Vicia sativa*, one of the early maturing and better branching performance gave relatively higher pod and flower proportion at Holetta. The late maturing vetch species, *Vicia atropurpurea,* gave the lowest green pod and flower proportion at Holetta. At Ginchi, *Vicia narbonensis* gave the highest pod and flower proportion followed by *Vicia sativa,* while *Vicia atropurpurea* gave the lowest proportion at forage harvest. The variation in morphological characteristics such as leaf, stem and panicle fractions of forage accounts for part of the difference in quality and these characteristics are important in the selection of forage crops that are agronomically suitable and used for various purposes such as for hay, silage, grazing etc. in a particular area (Getnet and Ledin, 2001).

Yields of morphological fractions and biomass production rate

Yields of morphological fractions such as leaf, stem and green pod and flower for vetch species had significant ($P<0.05$) difference at both locations (Table 4). The higher morphological yields were obtained at Ginchi than Holetta. Accordingly, on average the species gave 41.8, 33.2 and 19.1% more leaf, stem and green pod and flower DM yields respectively at Ginchi compared to Holetta. The estimated yields of morphological fractions at forage harvesting stage ranged from 0.51 to 1.46 t/ha for leaf DM; 0.70 to 3.50 t/ha for stem DM; and 0.17 to

Table 3: Least square means for proportions (%) of leaf, stem, and green pod and flower fractions on DM basis of vetch species at forage harvesting at Holetta and Ginchi.

	Leaf		Stem[!]		Green pod & flower	
Species	Holetta	Ginchi	Holetta	Ginchi	Holetta	Ginchi
Vicia sativa	32.0^{b}	34.9^{a}	52.8^{b}	51.7^{b}	18.1^{a}	13.5
Vicia villosa	25.2^{cd}	25.5^{b}	59.6^{a}	61.9^{a}	15.4^{a}	12.6
Vicia narbonensis	36.7^{a}	36.7^{a}	51.1^{b}	48.8^{b}	12.1^{bc}	14.5
Vicia dasycarpa	23.0^{d}	23.5^{b}	63.5^{a}	63.4^{a}	14.1^{ab}	13.1
Vicia atropurpurea	28.9^{bc}	28.8^{b}	63.3^{a}	63.6^{a}	7.7^{c}	7.6
Mean	**28.4**	**29.9**	**58.1**	**57.9**	**13.5**	**12.3**
CV (%)	**13.01**	**12.35**	**10.32**	**12.12**	**16.52**	**24.22**
R^2	**0.69**	**0.68**	**0.37**	**0.24**	**0.34**	**0.08**

Means followed by a common superscript letters with in a column are not significantly different from each other at P<0.05.

Table 4: Least square means for morphological fraction yields (t/ha) of vetch species grown at Holetta and Ginchi

	Leaf DM		Stem DM		Pod & flower DM	
Species	Holetta	Ginchi	Holetta	Ginchi	Holetta	Ginchi
Vicia sativa	1.46^{a}	2.26^{a}	2.69^{b}	3.49^{b}	0.90^{a}	1.04^{a}
Vicia villosa	1.44^{a}	1.93^{ab}	3.50^{a}	4.72^{a}	0.90^{a}	0.97^{a}
Vicia narbonensis	0.51^{b}	0.73^{c}	0.70^{c}	0.97^{c}	0.17^{c}	0.29^{b}
Vicia dasycarpa	1.25^{a}	1.62^{b}	3.44^{ab}	4.37^{ab}	0.77^{a}	0.90^{a}
Vicia atropurpurea	1.45^{a}	2.10^{ab}	3.24^{ab}	4.52^{ab}	0.40^{b}	0.52^{ab}
Mean	**1.22**	**1.73**	**2.71**	**3.61**	**0.63**	**0.75**
CV (%)	**13.24**	**10.47**	**9.81**	**10.26**	**11.6**	**19.13**
R^2	**0.70**	**0.73**	**0.84**	**0.79**	**0.77**	**0.33**

Means followed by a common superscript letters with in a column are not significantly different from each other at P<0.05.

0.90 t/ha for green pod and flower DM yield at Holetta, while 0.73 to 2.26 t/ha for leaf DM; 0.97 to 4.72 t/ha for stem DM; and 0.29 to 1.04 t/ha for green pod and flower DM yield at Ginchi. Among the species, *Vicia narbonensis* gave significantly lower (P<0.05) leaf, stem and green pod and flower DM yields than all the other vetch species at both locations. On the other extreme, *Vicia sativa* had comparatively higher leaf and green pod and flower DM yields at both locations, but higher stem DM yield was obtained from *Vicia villosa* at both locations. Herbage in combination with other characteristics like maturity, proportions of morphological fractions and nutritive value of the herbage yield are useful considerations in selecting the best variety for forage production (Arelovich et al., 1995). The biomass production rate was highly determined by environmental and genetic variability. Higher biomass production rate was recorded at Ginchi than Holetta. Biomass production rate for vetch species showed significant (P<0.05) difference at both locations and ranged from 12.8 to 50.3 kg/ha/day at Holetta, while 15.4 to 63.2 kg/ha/day at Ginchi (Table 5). A higher rate was recorded for *Vicia villosa* and *Vicia sativa* at Holetta and Ginchi respectively. On the other extreme, *Vicia atropurpurea* had significantly lower (P<0.05) rate than all species except *Vicia dasycarpa* at both locations. Generally, early maturing species had comparatively higher biomass production rate while late maturing species had lower biomass production rate at both locations. Tamene (2008) reported that there was significant positive gain in biomass production rate and strong association between grain yield and biomass production rate in faba bean.

Table 5: Least square means for biomass production rate (kg/ha/day) and total dry matter yield (t/ha) of vetch species grown at Holetta and Ginchi.

	Biomass production rate		Total DM	
Species	Holetta	Ginchi	Holetta	Ginchi
Vicia sativa	47.3[ab]	63.2[a]	5.05[a]	6.79[a]
Vicia villosa	50.3[a]	50.6[a]	5.84[a]	7.62[a]
Vicia narbonensis	47.8[ab]	61.7[a]	1.39[b]	1.99[b]
Vicia dasycarpa	29.3[bc]	40.7[ab]	5.46[a]	6.89[a]
Vicia atropurpurea	12.8[c]	15.4[b]	5.09[a]	7.14[a]
Mean	**37.5**	**46.3**	**4.56**	**6.09**
CV (%)	**16.44**	**15.79**	**21.12**	**21.14**
R^2	**0.25**	**0.21**	**0.84**	**0.74**

Means followed by a common superscript letters with in a column are not significantly different from each other at P<0.05.

Forage DM yield

Among vetch species, dry biomass forage yield varied across the testing sites. The higher total DM yield was obtained at Ginchi than Holetta. Accordingly, on average the species gave 33.6% more total herbage DM yield at Ginchi compared to Holetta. Total DM yield was different (P<0.05) at both locations and ranged from 1.39 to 5.84 and 1.99 to 7.62 t/ha 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* at forage harvest. Generally, intermediate to late maturing vetch species gave relatively better forage DM yield than the 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 the early maturing oats varieties. Muluneh (2006) reported that the yield of vetch species produced on red soil (Holetta) was more than double compared to the results recorded on black soil (Ginchi), because Ginchi site 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 on black soil than red soil during the cropping season. Because forage crops of this study were sown on camber-bed which minimized the water logging problem of vertisol and resulted relatively in higher biomass yield. In addition, there was relatively adequate and availability of well distributed rainfall during the cropping season at Ginchi.

Grain filling period and total grain sink filling rate

The grain filling period of vetch species differed significantly (P<0.05) at both locations, ranging from 46.9 to 72.4 days with a mean of 56.2 days and from 70.0 to 79.8 days with a mean of 76.1 days at Holetta and Ginchi respectively (Table 6). The highest grain filling period was recorded for *Vicia villosa* at Holetta and *Vicia sativa* at Ginchi, whereas the lowest period was recorded for *Vicia sativa* and *Vicia narbonensis* at Holetta and Ginchi respectively. In general, most of the species started flowering early and had shorter grain filling period. However, some of the vetch species in this study showed early to start flowering, but took longer period to fill the grain. Location had affected (P<0.05) grain sink filling rate of vetch species, which ranged from 7.2 to 16.4 kg/ha/day with a mean of 11.4 kg/ha/day at Holetta and from 26.0 to 41.0 kg/ha/day with a mean of 31.6 kg ha^{-1} day^{-1} at Ginchi (Table 6). The rate was the highest for *Vicia sativa* (16.4 kg/ ha/day) at Holetta and for *Vicia narbonensis* (41.0 kg/ha/day) at Ginchi, whereas the lowest rate was recorded for *Vicia narbonensis* (7.2 kg/ha/day) at Holetta and for *Vicia dasycarpa* (27.8 kg/ ha/day) at Ginchi. Grain sink filling rate is directly related to the seed yield. Improvement in gain sink filling rate is an important task for maximum seed yield production of any crop. According to Yifru (1998), tef grain yield improvement over thirty five years of research has been

Table 6: Least square means for grain filling period (days) and grain sink filling rate (kg/ha/day) of vetch species at Holetta and Ginchi.

	Grain filling period		Grain sink filling rate	
Species	Holetta	Ginchi	Holetta	Ginchi
Vicia sativa	46.9^{c}	79.8^{a}	16.4^{a}	33.9^{a}
Vicia villosa	72.4^{a}	78.6^{a}	10.2^{b}	29.1^{ab}
Vicia narbonensis	56.9^{b}	70.0^{b}	7.2^{c}	41.0^{a}
Vicia dasycarpa	51.8^{bc}	78.8^{a}	13.6^{ab}	26.0^{b}
Vicia atropurpurea	53.0^{bc}	73.3^{ab}	9.5^{bc}	27.8^{ab}
Mean	**56.2**	**76.1**	**11.4**	**31.6**
CV (%)	**12.85**	**8.00**	**13.17**	**8.86**
R^2	**0.68**	**0.35**	**0.29**	**0.19**

Means followed by a common superscript letters with in a column are not significantly different from each other at P<0.05.

Table 7: Least square means for seed yield (t/ha) and thousand seed weight (g) of vetch species at Holetta and Ginchi.

	Seed yield		Thousand seed weight	
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**

Means followed by a common superscript letters with in a column are not significantly different from each other at P<0.05.

associated mostly with corresponding increase in panicle grain sink filling rate and panicle yield. Tamene (2008) also reported that sizeable improvement was made in economic growth rate and biomass production rate in faba bean breeding.

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 with a mean of 0.6 t/ha at Holetta and from 2.0 to 2.9 t/ha with a mean of 2.4 t/ha at Ginchi (Table 7). The highest seed yield was obtained from *Vicia sativa* (0.8 t/ha) at Holetta and *Vicia narbonensis* (2.9 t/ha) at Ginchi, whereas the lowest yield was obtained from *Vicia narbonensis* (0.4 t/ha) at Holetta and *Vicia atropurpurea* (2.0 t/ha) at Ginchi. Thousand seed weight of vetch species 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 7). 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. Though *Vicia narbonensis* had the highest thousand seed weight, its seed yield was relatively lower due to lower establishment performance at Holetta. Unless the establishment performance is poor, species with high thousand seed weight has higher seed yield. Getnet et al., (2003) and Fekede (2004) also reported that most of the oats varieties with high grain yield showed higher 1000 kernel weight. In general, vetch species (*V. narbonensis* and *V. sativa*) which have an erect growth habit and early maturing had comparatively higher thousand seed weight than creeping growth habit and intermediate to late maturing vetch species. The difference 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 8: Least square means for number of pods per plant, pod length (cm) and number of seeds per pod of vetch species at Holetta and Ginchi.

Species	No. of pods/plant[5]		Pod length		No. of seeds/pod	
	Holetta	Ginchi	Holetta	Ginchi	Holetta	Ginchi
Vicia sativa	32.3[b]	45.7[c]	5.3[a]	5.3[b]	7.0[a]	7.4[a]
Vicia villosa	85.3[a]	41.2[ab]	2.7[b]	2.8[c]	3.9[c]	4.3[c]
Vicia narbonensis	7.6[c]	30.6[d]	5.4[a]	5.5[a]	4.8[b]	5.2[b]
Vicia dasycarpa	85.1[a]	159.1[a]	2.8[b]	3.0[c]	4.0[c]	4.4[c]
Vicia atropurpurea	80.5[a]	110.6[b]	2.7[b]	3.1[c]	4.2[c]	4.9[bc]
Mean	**58.2**	**97.4**	**3.8**	**3.9**	**4.8**	**5.2**
CV (%)	**10.62**	**13.78**	**5.61**	**5.93**	**8.20**	**8.52**
R^2	**0.94**	**0.87**	**0.97**	**0.96**	**0.92**	**0.90**

Means followed by a common superscript letters with in a column are not significantly different from each other at P<0.05.

Seed yield components

The number of pods per plant was counted at the optimum seed setting stage due to indeterminate growth nature of the crop. The number of pods per plant for vetch species varied significantly (P<0.05) at both locations which ranged from 7.6 to 85.3 with a mean of 58.2 at Holetta and 30.6 to 159.1 with a mean of 97.4 at Ginchi (Table 8). The highest number of pods per plant was counted for *Vicia villosa* at Holetta and *Vicia dasycarpa* at Ginchi, whereas the lowest was counted for *Vicia narbonensis* at both locations. In general, branching or tillering performance of the plant has a direct effect on number of pods per plant and hence vetch species with a higher branching or tillering performance has higher number of pods per plant. The pod length of vetch species differed significantly (P<0.05) at both locations and ranged from 2.7 to 5.4 cm with a mean of 3.8 cm at Holetta and 2.8 to 5.5 cm with a mean of 3.9 cm at Ginchi (Table 8). The result showed that *Vicia narbonensis* had comparatively the longest pod length than all the other vetch species at both locations. *Vicia villosa* had the shortest pod length at both locations. Pod length has a direct effect on number of seeds per pod and indirect effect on seed yield. It was observed that vetch species with an erect growth habit and early maturing had higher pod length than creeping growth type with an intermediate to late maturing dates. The number of seeds per pod for vetch species varied (P<0.05) at both locations, which ranged from 3.9 to 7.0 with a mean of 4.8 at Holetta and from 4.3 to 7.4 with a mean of 5.2 at Ginchi (Table 8). *Vicia sativa* had significantly higher (P<0.05) number of seeds per pod at both locations. Number of seeds per pod is highly related with pod length and seed size and hence the number of seeds per pod for most vetch species increased with increasing pod length. Though *Vicia narbonensis* had the longest pod length, the highest number of seeds per pod was obtained from *Vicia sativa*, because the seed size of *Vicia narbonensis* is larger than *Vicia sativa*. The early maturing vetch species that are normally an erect growth habit had larger seed size compared to other vetch species. In addition to this feature it was also found that these species had higher number of seeds per pod. Generally, early maturing species had the highest seed yield due to larger seed size and longer pod length compared to the other vetch species.

Forage ash content

The ash content of vetch species was found to be higher at Ginchi at forage harvesting stage. Concentration of minerals in forage varies due to factors like plant developmental stage, morphological fractions, climatic conditions, soil characteristics and fertilization regime (Greene, 2000; McDowell and Valle, 2000; Jukenvicius and Sabiene, 2007). The ash content of vetch species in this study showed significant (P<0.05) difference at both locations, ranging from 7.7 to 10.4% with a mean of 8.8% and from 6.7 to 9.5% with a mean of 8.3% at Holetta and Ginchi respectively (Table 9). The average ash content was highest in *Vicia dasycarpa,* and the lowest in *Vicia sativa* at both locations. The high ash content in *Vicia dasycarpa* could be an indication of high mineral concentration. Intermediate to late maturing vetch species had relatively higher ash content than early maturing species, which could be due to differences in proportions and composition of morphological fractions. Fekede (2004) also reported that late maturing or low grain producing oats varieties had comparatively higher ash content in their whole forage DM than early maturing or high grain producing oats varieties. In addition to higher CP content, herbaceous forage legumes have higher content of some minerals like Calcium, Sulfur and possibly Phosphorus than grasses, and well nodulated legumes contain large amount of calcium, magnesium and other essential elements (Jennings, 2004). The high

Table 9: Least square means for ash and CP on (%) DM basis of vetch species at Holetta and Ginchi

	Ash%		CP%	
Species	Holetta	Ginchi	Holetta	Ginchi
Vicia sativa	7.7^{c}	6.7^{d}	18.9^{e}	18.9^{e}
Vicia villosa	9.0^{b}	7.9^{c}	21.4^{d}	21.6^{d}
Vicia narbonensis	8.2^{c}	9.0^{ab}	22.4^{c}	22.4^{c}
Vicia dasycarpa	10.4^{a}	9.5^{a}	25.8^{a}	26.0^{a}
Vicia atropurpurea	8.7^{bc}	8.3^{bc}	23.4^{b}	23.6^{b}
Mean	**8.8**	**8.3**	**22.4**	**22.5**
CV (%)	**10.01**	**9.76**	**0.61**	**0.95**
R^2	**0.51**	**0.65**	**0.99**	**0.97**

Means followed by a common superscript letters with in a column are not significantly different from each other at P<0.05.

ash content in forage could be an indication of high mineral concentration. The results suggest that the mineral content of most herbaceous plants was reduced with increased stage of maturity. After energy and protein, minerals are the major nutrients required and should be given priority in order to optimize reproduction in dairy cattle (Bindari et al., 2013). Minerals are required in reproductive process because of their role in maintenance, metabolism and growth (Hadiya et al., 2010). The availability of minerals to cattle depends upon the production system, feeding practices, and environment (Singh and Bohra, 2005). Mineral deficiencies are likely to lead to depressed feed intake, forage utilization and subsequently poor animal performance (Underwood, 1981).

Forage crude protein content

The CP content also showed significant (P<0.05) difference among vetch species at both locations at forage harvesting stage (Table 9). The CP content of the species at forage harvest 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. They found that the CP content of vetch was 18.9%, which is similar to good alfalfa forage and with this level of CP, vetch could be used as a supplement to roughages for dairy cows. Most of the 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 pasture and crop residues (Norton, 1982). In general, the results in this study indicated that intermediate maturing species such as *Vicia dasycarpa* and *Vicia atropurpurea* had comparatively higher CP content whereas early and late maturing species such as *Vicia sativa*, *Vicia narbonensis* and *Vicia villosa* had comparatively lower CP content at both locations. Legumes confer several advantages in the context of animal nutrition; their higher protein content relative to that of grasses has long been recognized (Getnet and Ledin, 2001), and provide quality feed for livestock due to higher CP content (Daniel, 1996; Ikwvegbu et al., 1996). Legumes in general and vetch in particular are excellent sources of N for livestock feed (Seyoum, 1994), vetch has a higher CP content compared to many other tropical herbaceous legumes (Getnet and Ledin, 2001), the importance of forage legumes in livestock and crop production is well recognized (McDolad et al., 1995; Getnet, 1999).

Forage fiber content

The 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 10). *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. The NDF contents above the critical value of 60% result in decreased voluntary feed intake, feed conversion efficiency and longer rumination time (Shirley, 1986; 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 (Dien et al., 2006) and at maturity,

Table 10: Least square means for NDF and *in-vitro* dry matter digestibility (IVDMD) on DM basis of vetch species at Holetta and Ginchi.

	NDF%		IVDMD%	
Species	Holetta	Ginchi	Holetta	Ginchi
Vicia sativa	55.2[a]	39.5[b]	60.5[e]	60.3[e]
Vicia villosa	51.6[ab]	43.9[b]	66.4[c]	66.2[c]
Vicia narbonensis	54.4[a]	54.3[a]	66.5[b]	66.4[b]
Vicia dasycarpa	44.7[bc]	39.7[b]	73.4[a]	73.2[a]
Vicia atropurpurea	36.5[c]	41.7[b]	65.6[d]	65.5[d]
Mean	**48.5**	**43.8**	**66.5**	**66.3**
CV (%)	**7.79**	**12.35**	**0.15**	**0.14**
R^2	**0.42**	**0.24**	**1.00**	**1.00**

Means followed by a common superscript letters with in a column are not significantly different from each other at P<0.05.

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). In general, early maturing and an erect growing type of vetch species had comparatively higher NDF content than intermediate to late maturing and creeping type of vetch species. The higher fiber concentration is found in both the leaf and stem fractions of grasses compared to legumes. Digestibility decreased with advancing age. This decline resulted from the interaction of factors such as increased fiber concentration in plant tissue, increased lignifications during plant development and decreased leaf to stem ratio (Wilson et al., 1991). Increasing dietary NDF concentration most often has a negative impact on the amount of DM consumed by lactating dairy cows, which generally translates into reduced milk production (Allen, 2000). However, legume fibers ferment more rapidly in the rumen that is why ruminants can consume larger amounts of legumes than grasses (Hinders, 1995).

Forage digestibility

The overall average *in-vitro* dry matter digestibility (IVDMD) was not different at Holetta (66.5%) and Ginchi (66.3%), but the species were significantly different at both locations (Table 10). 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 result in higher voluntary intake and digestibility of vetch species and this result also supported by Getnet and Ledin (2001). The IVDMD is positively correlated to the CP content and inversely related to the fiber content (NDF and ADF) and cell walls constituents (ADL, cellulose and hemi cellulose) for most vetch species. It was generally observed that early maturing vetch species 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 (Zinash et al., 1995; Yihalem, 2004; Tessema, 2003; Adane, 2003); fiber and cell wall constituents (Van Soest, 1994; Mustafa et al., 2000); proportions of morphological fractions (McDonald et al., 1995; Fekede, 2004); soil, plant species and climate (McDowell, 2003). Temperature is among the environmental factors that have a direct influence on forage quality. A rise in temperature increases cell wall constituents, increase lignifications, decrease soluble carbohydrate concentration and decrease digestibility (Pearson and Ison, 1997). It also reduces the leaf to stem ratio of forage, which directly affects the digestibility of the forage dry matter because of the lower digestibility of the stems in relation to the leaf (Buxton et al., 1995).

CONCLUSION

Vetch species had variations in terms of agronomic performance and herbage quality. *Vicia narbonensis* had shorter vegetative and grain filling period, whereas *Vicia atropurpurea* and *Vicia villosa* had longer vegetative and grain filling period respectively. This difference among vetch species is an important agronomic trait to select companion crops for optimum production. The tallest stretched and un-stretched plant heights were recorded for *Vicia dasycarpa* and *Vicia atropurpurea* at Holetta and

Ginchi respectively. On the other hand, *Vicia narbonensis* had the shortest plant height at both locations. Vetch species which have an erect growth habit and shorter plant height showed fast biomass production rate at forage harvesting stage than creeping and taller plants. Average total DM yield and its botanical fraction yields were higher at Ginchi than Holetta. *Vicia villosa* gave relatively higher total DM yield, whereas *Vicia narbonensis* gave the lowest total DM yield at Holetta and Ginchi respectively. Late maturing vetch species gave higher forage DM and its morphological fraction yields than early maturing vetch species at both locations. The seed yield and its related performance were also highly influenced by environment and hence comparatively higher seed yield and its related performance were obtained at Ginchi than Holetta. Early maturing vetch species had comparatively shorter grain filling period and higher grain sink filling rate than intermediate to late maturing species. The highest number of pods per plant was obtained from *Vicia villosa* at Holetta and *Vicia dasycarpa* at Ginchi, whereas *Vicia narbonensis* had the lowest at Holetta and Ginchi. The highest pod length was obtained from *Vicia narbonensis*, and *Vicia sativa* gave the highest number of seeds per pod at Holetta and Ginchi. *Vicia sativa* and *Vicia narbonensis* gave the highest seed yield at Holetta and Ginchi respectively. The highest thousand seed weight was recorded for *Vicia narbonensis* at Holetta and Ginchi, whereas the lowest for *Vicia dasycarpa* and *Vicia villosa* at Holetta and Ginchi respectively. Forage quality of vetch species varied across testing sites at forage harvesting. *Vicia dasycarpa* had the highest ash content, CP content and IVDMD than the remaining vetch species at Holetta and Ginchi. In most measured parameters, intermediate to late maturing vetch species had comparatively better ash, CP and IVDMD, but lower fiber content than early maturing vetch species. Generally, vetch species have different phenology, forage and seed productivity and forage quality.

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