ORIGINAL ARTICLE

Evaluation of Forage yield and yield Components of Different Vetch Species and their Accessions Grown under Nitosol and Vertisol Conditions in the Central Highlands of Ethiopia

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ABSTRACT

Twenty accessions of five vicia species were evaluated for their agro-morphological differences at Holetta and Ginchi in Ethiopia. The experiment was conducted in RCBD with three replications. Data on establishment performance, growth rate, phenology, plant height, proportions of morphological fractions, biomass production rate and forage yield were collected and analyzed. Most measured parameters showed significant ($P<0.05$) difference among the tested vetch species and their accessions at both locations. Shorter days to emergence, higher vigor and lower seedling count per square meter at the early stage of growth, and lower aerial DM accumulations, lower branching performance, and shorter plant height over the growing period were recorded at Holeta and Ginchi. The difference between late and early maturing species for forage harvest was 25.0 days at Holetta and 27.9 days at Ginchi. Early maturing species had higher biomass production rate and the difference between the highest and the lowest was 37.5 kg $ha^{-1}day^{-1}$ at Holetta and 47.8 kg $ha^{-1}day^{-1}$ at Ginchi, and lower number of branches with the difference of 9.46 at Holetta and 12.13 at Ginchi. Taller vetch species gave better forage DM yield at forage harvest. Correlation analysis was also done for major production traits to select the accessions for desired traits. Accordingly, forage dry matter yield showed a strong ($P<0.001$) positive correlation with days to forage harvest ($r = 0.78$) and plant height ($r = 0.79$), but leaf to stem ratio was negatively correlated ($P<0.001$) with days to forage harvest ($r = - 0.87$), plant height ($r = - 0.91$) and forage yield ($r = - 0.76$). Generally, the result indicated the presence of considerable variations in phenology, plant height, proportion of morphological fractions and their yields of vetch species and their accessions thereby suggesting the possibility of improving vetch production through proper exploitation of the genetic resource differences.

Key words:biomass production rate,dry matter accumulation, forage,morphological fractions, vetch

INTRODUCTION

The livestock population of Ethiopia is currently estimated to be about 53.99 million cattle, 25.49 million sheep, 24.06 million goats, 1.91 million horses, 6.75 million donkeys, 0.35 million mules, 0.92 million camels, 50.38 million poultry and 5.21 million beehives (CSA, 2013). In many developing countries, livestock play an important role in the livelihoods of most small-scale farmers, viz, sources of food in the form of meat and milk, services (transport and draught power), cash income, manure (for soil fertility management and fuel) and serve as store of wealth and hedge against inflation (Sere *et al*., 2008). The highlands of Ethiopia are characterized by crop-livestock mixed farming systems and inhabited by high human and livestock populations. About 88% of the human, 75% of the cattle, 75% of the sheep and 34% of the goat population in Ethiopia are found in the highlands (CSA, 2008). High density of human and livestock population ranging between 37-120 people and 27-130 tropical livestock unit (TLU) per square kilometer is one of the major reasons for severe degradation of the natural resource base resulting in poor animal nutrition (CSA, 2008).

Despite enormous contribution of livestock to the livelihood of farmers, availability of poor quality feed resources remains to be the major bottleneck to livestock production in the highlands of Ethiopia (Seyoum and Zinash, 1995). According to Lulseged (1987), overstocking and overgrazing have resulted in the disappearance of valuable species, spread of unpalatable species, *Pennisetum shemperi*, and land degradation is a common situation in the highlands of Ethiopia. Traditional livestock production system mainly depends upon poor pasturelands and crop residues which are usually inadequate to support reasonable livestock production (Tsige, 2000; Assefa, 2005). Crop residues provide on average about 50% of the total feed source for ruminant livestock and its contribution reach up to 80% during the dry seasons of the year in the highlands of Ethiopia (Adugna, 2007). These feed resources are high in fiber, with low to moderate digestibility and low levels of nitrogen (Preston, 1995; Tsige, 2000). Such low quality feeds are associated with a low voluntary intake, thus resulting in insufficient nutrient supply, low productivity and even weight loss (Hindrichsen *et al*., 2004). But forage legumes have lower contents of structural fiber, higher protein contents and greater digestibility, resulting in higher nutrient intake rates and animal production when they are used as fodder (Frame *et al*., 1998).

In order to mitigate the feed shortage problems in crop-livestock production system, integration of improved forage crops into the farming systems through different methods are highly important and appropriate in areas where land shortage is a problem and the agricultural production system is subsistence (Getnet *et al*., 2003). Berhanu *et al*., (2003) also reported that improved animal nutrition through adoption of sown forage could substantially increase livestock productivity. Vetch species are the most important and widely utilized annual forage legumes in the highland farming systems throughout different production strategies in Ethiopia (Alemayehu and Lazier, 1989; Getnet *et al*., 2003). It grows well on the reddish brown clay soils and the black soils of the highland areas. It has been grown successfully in areas of acid soil with pH of 5.5-6 (IAR, 1980). According to Seyoum (1994), forage legumes like vetch is rich sources of N for livestock with cheaper prices compared to concentrates especially in developing countries. Its high value, as protein supplement for ruminants on low quality diets has been recorded (Alzueta *et al*., 2001; Pariyar, 2002).

Adaptation and number of annual forage legumes in the highlands of Ethiopia is comparatively very low when compared to mid and low altitudes due to mainly climatic and soil factors. Information on agro-morphological characteristics of vetch species and their accessions are very crucial for proper production, utilization and conservation. However, previous evaluations of vetches in the highlands have been done mainly on environmental adaptation and biomass yield but there is no adequate assessment of accessions of different vetch species with respect to basic quantitative traits to mitigate the feed shortage of mixed farming systems. Therefore, this study was designed to determine the differences in morphological and agronomical traits of different vetch species and their accessions under the two soil types in the central highlands of Ethiopia.

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 for one year during the main cropping season of 2009 under rain fed condition. 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 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 temperature of 22.2°C and 6.1°C respectively. 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 temperature of 24.6°C and 8.4°C respectively. The soil of the area is predominantly 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).

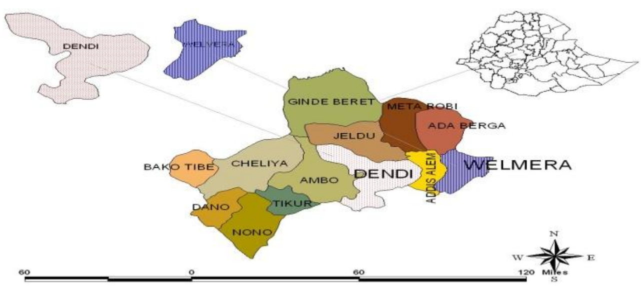

Figure 1. Map of the experimental sites, at Holetta (Welmera) and Ginchi (Dendi) in the central highlands of Ethiopia.

Experimental Treatments and Design

All accessions of *Vicia narbonensis*, *Vicia villosa* and *Vicia sativa* were introduced from International Center for Agricultural Research in the Dry Areas (ICARDA); *Vicia dasycarpa* and *Vicia atropurpurea* accessions were initially introduced from Australia to HARC in different years. The study was conducted using 20 accessions from five vetch species (Table 1) in a Randomized Complete Block Design (RCBD) with three replications. Seeds were sown in rows with 30 cm spacing 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* (HARC, 1999; HARC, 2002). 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. Generally, maximum care was taken in the experimental plots to reduce the possible yield limiting factors such as weeds and water-logging which could affect yield performance of vetch species and their accessions.

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

Treat.	Species	Accessions	Treat.	Species	Accessions
1	*Vicia sativa*	64266	11	*Vicia villosa*	2434
2	*Vicia sativa*	61904	12	*Vicia villosa*	2446
3	*Vicia sativa*	61744	13	*Vicia narbonensis*	2384
4	*Vicia sativa*	61509	14	*Vicia narbonensis*	2387
5	*Vicia sativa*	61039	15	*Vicia narbonensis*	2376
6	*Vicia. sativa*	61212	16	*Vicia narbonensis*	2392
7	*Vicia villosa*	2565	17	*Vicia narbonensis*	2380
8	*Vicia villosa*	2450	18	*Vicia dasycarpa*	Namoi
9	*Vicia villosa*	2424	19	*Vicia dasycarpa*	Lana
10	*Vicia villosa*	2438	20	*Vicia atropurpurea*	Atropurpurea

Sampling Procedures and Data Collection

Days to emergence was recorded as number of days from date of sowing to the day when the majority (90%) of the planted seeds have emerged just above the ground (Aklilu and Alemayehu, 2007). Stand vigor was also taken by visual observation from 1 to 5 (1 = the weakest, or least vigorous and 5 = the strongest, or most vigorous). Seedlings count per meter square at 20 days after sowing (DAS) was also done to assess the establishment performance (Getnet and Ledin, 2001). In order to assess the change of dry matter (DM) accumulation over the growing period, six plants were randomly taken using destructive sampling method in every 10 days beginning from 64 to 114 DAS (Getnet, 1999) and six such measurements were made during the growing period. The plants were uprooted and the aerial and root parts of the plants were separated manually. Fresh biomass yield of the aerial part was weighed and the samples were oven-dried at 65°C for 72 hours to determine the change of the aerial dry matter (DM) accumulation (Getnet and Ledin, 2001). The height of harvested plants was taken from the ground to the tip of the plants at each sampling period (Aklilu and Alemayehu, 2007).

Days to forage harvesting was counted from days to emergence to the date when plants reach 50% flowering stage (Aklilu and Alemayehu, 2007). Six plants were randomly taken from each plot and their heights were measured from ground to the tip of the plant at the time of 50% flowering. For determination of biomass yield, accessions of vetch were harvested at 50% flowering. Weight of the total fresh biomass yield was recorded from each plot in the field and sample was taken from each plot to the laboratory, oven dried for 72 hours at a temperature of 65^oC (Getnet and Ledin, 2001). The oven dried samples were weighed to determine the total dry matter yield. The second sample taken from each plot was weighed to know the total 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, and then oven dried for 72 hours at a temperature of 65^oC and separately weighed to estimate the proportions of these morphological parts (Getnet and Ledin, 2001). Proportion of each morphological fraction in percent was then computed as the ratio of each dry biomass fraction to total dry biomass multiplied by 100 (Fekede *et al*., 2008). Leaf, stem, and green pod and flower yields t ha^{-1} were also estimated by multiplying each proportion of botanical fraction by total dry biomass yield and then divided by 100 (Getnet and Ledin, 2001). Biomass production rate also computed by dividing the above ground biomass yield to number of days to 50% flowering and expressed as kg ha^{-1} day^{-1} (Wondimu, 2010).

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 experimental measurements. Logarithmic, square root and arcsine transformations were used for data which couldn't exhibit homogeneity of variance 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 Spearman rank-order correlation analysis procedure of the SAS statistical package was also applied to measure the strength of linear dependence between two measured variables. The data was analyzed using the following model: $Y_{ij} = \mu + T_i + B_j + e_{ij}$, where, Y_{ij}= measured response of treatment i in block j, μ= grand mean of the experiment, T_i= effect of treatment i, B_j= effect of block j, e_{ij}= random error effect of treatment i in block j.

RESULTS AND DISCUSSION

Establishment Performance

Study on establishment performance is an important consideration during forage crop cultivation due to substantial effect on forage yield. The result showed that early germination and vigorous growth of different vetch species and their accessions were recorded at Holetta than Ginchi. However, higher number of seedling per square meter was counted at Ginchi than at Holetta during 20 DAS. Generally, establishment performance varied across testing sites due to soil and climatic variations. According to Fekede (2004), high germination rate, vigorous growth and dense establishment are among the desired characteristics for forage crop variety. Days to emergence, vigor and seedling count of different vetch species and their accessions are presented in Table 2 and 3. Days to emergence of seedling of different vetch species and their accessions were significant ($P<0.05$) at both locations.

Table 2. Least square means for days to emergence and vigor of vetch species at Holetta andGinchi

Species	Days to emergence		Vigor$^{\Phi}$*		Seedling count@	
	Holetta	Ginchi	Holetta	Ginchi	Holetta	Ginchi
Vicia sativa	6.5[b]	8.2[ab]	4.3[a]	4.2	95.1[ab]	144.0[a]
Viciavillosa	6.6[b]	7.4[bc]	4.4[a]	3.6	115.9[a]	135.2[a]
Vicianarbonensis	7.6[a]	7.1[c]	3.7[b]	4.0	91.5[b]	129.8[a]
Viciadasycarpa	8.3[a]	9.3[a]	4.6[a]	3.7	77.7[bc]	112.2[ab]
Viciaatropurpurea	8.7[a]	6.7[c]	4.5[a]	4.3	51.3[c]	70.7[b]
Mean	7.5	7.8	4.2	3.9	86.3	118.4
CV (%)	17.3	18.1	7.3	12.2	15.9	16.1
P-value	0.0011	0.0100	0.0001	0.0631	0.0031	0.0338

Within column means with different superscripts differ significantly (P<0.05);$^{\Phi}$= log transformation, @ = Square root transformation, *= vigour scale 1-5: 1= very small; 2= small; 3= medium; 4=large and 5= very large

As described by Pal (2004), seed size, sowing depth, land preparation, and environment influences the emergence of seedlings. There was differences (P<0.05) in vigor among the species of vetch at Holetta but not at Ginchi. The reason for low vigor of species as well as accessions of vetch at Ginchi trial site could be due to the higher number of population per plot existed and caused high competition for the limited growth resources and resulted in low vigor at the early stage of growth. Variation in soil factors also had their own contribution for the existence of low vigor at Ginchi when compared to Holetta. Muluneh (2006) reported that vigor was significantly affected by difference in the soil as seedlings showed better growth on red soil (Holetta) than black soil (Ginchi) which might be related to poor drainage in vertisol and fertility difference between the soils.

An average seedling count at the 20th days of sowing was higher at Ginchi compared to Holetta (Table 2 and 3). A higher number of seedling count (P<0.05) was recorded for *Vicia villosa* followed by *Vicia sativa* at Holetta, and *Vicia sativa* followed by *Vicia villosa at Ginchi*. Getnet and Ledin (2001) also reported that *Vicia villosa* germinated more densely than the other vetch species sown in pure stands and mixtures with oats on red and black soils. The reason for a higher number of seedling counts at Ginchi than Holetta could be due to relatively warmer temperature and high rainfall during the cropping season that facilitated the germination potential of the seeds. The other factor affecting the number of seedling per unit area is thousand seed weight. Species with smaller seed size has higher seedling per unit area due to higher number of seeds sown per unit area than species with larger seed size. The germination performance under variable field conditions and seeding rates are also factors affecting plant population per unit area. Generally, longer days to emergence, higher seedling count per unit area and low vigor were observed at Ginchi than Holetta during the initial stage of growth.

Table 3. Average days to emergence and vigor of vetch accessions grown at Holetta and Ginchi

		Days to emergence		Vigor $^{\Phi}$*		Seedling count	
Species	Accessions	Holetta	Ginchi	Holetta	Ginchi	Holetta	Ginchi
Vicia sativa	64266	5.3[d]	7.0[bcd]	4.5[ab]	3.5[bcde]	123.3	177.0
V. sativa	61904	6.3[bcd]	6.7[bcd]	4.5[ab]	4.0[abcde]	90.0	137.3
V. sativa	61744	7.7[abcd]	9.0[ab]	4.2[abcd]	4.7[ab]	103.0	171.0
V. sativa	61509	6.7[bcd]	8.3[abcd]	4.3[abc]	4.3[abcd]	92.3	150.7
V. sativa	61039	7.0[bcd]	9.7[a]	4.2[abcd]	4.0[abcde]	71.7	97.7
V. sativa	61212	6.0[cd]	8.3[abcd]	4.3[abc]	4.8[a]	90.3	130.3
V. villosa	2565	6.0[cd]	8.3[abcd]	4.3[abc]	3.0[e]	102.7	130.3
V. villosa	2450	7.7[abcd]	7.3[abcd]	4.0[abcd]	3.7[abcde]	118.0	138.0
V. villosa	2424	6.3[bcd]	7.7[abcd]	4.5[ab]	3.8[abcde]	115.0	151.3
V. villosa	2438	6.3[bcd]	8.3[abcd]	4.5[ab]	3.7[abcde]	117.7	117.0
V. villosa	2434	6.7[bcd]	6.3[cd]	4.7[a]	4.2[abcd]	111.3	148.7
V. villosa	2446	6.3[bcd]	6.7[bcd]	4.2[abcd]	3.5[bcde]	131.0	125.7
V. narbonensis	2384	7.7[abcd]	6.3[cd]	4.2[abcd]	4.5[abc]	83.7	118.7
V. narbonensis	2387	7.3[abcd]	7.3[abcd]	3.2[e]	3.5[bcde]	109.7	143.3
V. narbonensis	2376	6.7[bcd]	7.3[abcd]	3.5[de]	3.8[abcde]	76.0	121.7
V. narbonensis	2392	8.0[abc]	6.0[d]	3.7[cde]	3.8[abcde]	92.3	128.0
V. narbonensis	2380	8.3[abc]	8.7[abc]	3.8[bcd]	4.2[abcd]	96.0	137.3
V. dasycarpa	Namoi	9.3[a]	9.0[ab]	4.5[ab]	3.3[de]	79.3	100.0
V. dasycarpa	Lana	7.3[abcd]	9.7[a]	4.7[a]	4.0[abcde]	76.0	124.3
V. atropurpurea	Atropurpurea	8.7[ab]	6.7[bcd]	4.5[ab]	4.3[abcd]	51.3	70.7
	Mean	7.1	7.7	4.2	3.9	96.5	131.0
	CV (%)	16.8	16.3	6.9	11.1	34.6	31.9
	P-value	0.0214	0.0098	0.0008	0.0336	0.3972	0.4571

Within column means with different superscripts differ significantly (P<0.05); $^{\Phi}$ = log transformation, *= vigour scale 1-5: 1= very small; 2= small; 3= medium; 4=large and 5= very large

Changes in dry Matter (DM) Accumulation and Plant Height

Changes in DM and plant height of different vetch species over the sampling period was evaluated by sampling 6 plants in every 10 days starting from 64 DAS. Mean aerial DM accumulation and growth in height of vetch species grown at Holetta and Ginchi is presented in Figure 2. The result showed that the rate of aerial DM accumulation and growth in height during the initial sampling was generally low, but for the other subsequent samplings, the rate of DM accumulation and growth in height increased with faster rates at both locations. The rate of DM accumulation and growth in height were similar during the initial stage of growth at both locations. However, after the second sampling (74 DAS), aerial DM accumulation varied widely across the testing sites. Consequently, higher aerial DM was obtained at Ginchi than Holetta over the sampling period. Unlike aerial DM accumulation, growth in height was less affected by locations over the sampling period. However, after the third sampling (84 DAS), growth in height relatively varied across the testing sites and higher plant height was recorded at Ginchi.

Mean aerial DM accumulation of all the species combined over locations is presented in Figure 3a. The result revealed that there was an increasing trend of aerial DM accumulation for all species over the sampling period. This may be related to an increase in branching and leaf area that resulted in higher DM at the later stage of sampling. Between the first two initial samplings, higher and faster DM was obtained from all species than the other subsequent samplings and the increments ranged from 206 to 482 %. Fekede (2004) also reported that the rate of aerial DM accumulation for 20 oats varieties were higher between the initial two samplings (between 34 and 49 DAS). Over the sampling period, *Vicia dasycarpa* accumulated higher and faster aerial DM followed by *Vicia atropurpurea*, *Vicia villosa*, *Vicia sativa* and *Vicia narbonensis*. Singh *et al*. (2004), reported that dry matter partitioning to leaves decreased throughout the growing season while to that of stem increased up to anthesis and thereafter decreased up to physiological maturity in wheat. Mean plant height of five vetch species combined over locations is also presented in Figure 3b. Generally, *Vicia atropurpurea* was taller at each sampling period followed by *Vicia dasycarpa*, and *Vicia villosa* over the growing period. Generally, species of vetch performed differently in growth rate. This could be attributed to differences in biomass production rate, phenology (earliness and lateness), and inherent biomass yield performances. These differences are advantageous for selecting compatible crops and the type of appropriate integration method for maximum production. Generally, the difference in growth rates across the testing sites could be due to the difference in temperature, rainfall and soil fertility conditions. Black soil (vertisol) is inherently fertile but the problem is water-logging and aeration. The productivity of vertisol can be increased by draining excess water from the field. According to Getachew *et al*. (2007), the broad beds and furrows (BBF) and ridges and furrows (RF) surface drainage methods increased mean grain yields of chickpea by 59 and 46% respectively compared to flatbed conditions.

Days to Forage Harvest, Plant Height and Number of Branches at Forage Harvest

Days to forage harvest for tested vetch species and their accessions varied across the sites. Though Ginchi site is relatively warmer than Holetta, early maturity for forage was 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 harvesting stage. 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 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 vetches. On the other hand, days to forage harvest for accessions showed significant ($P<0.05$) difference at Holetta and Ginchi (Table 5). 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.

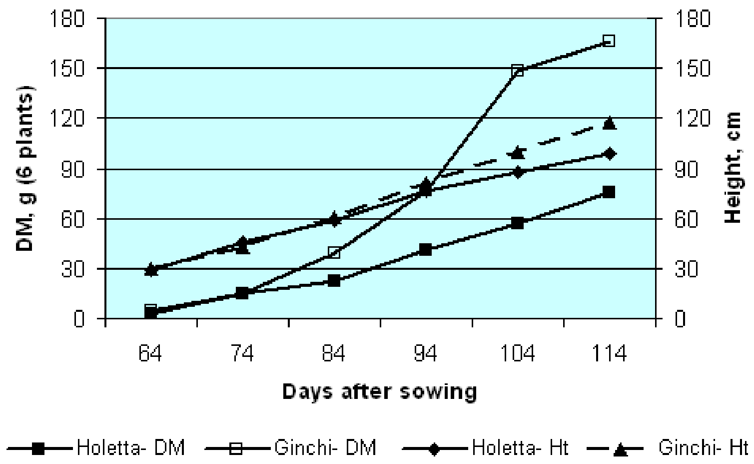

Figure 2. Mean aerial DM accumulation and growth in height of 20 accessions of vetch grown at Holetta and Ginchi.

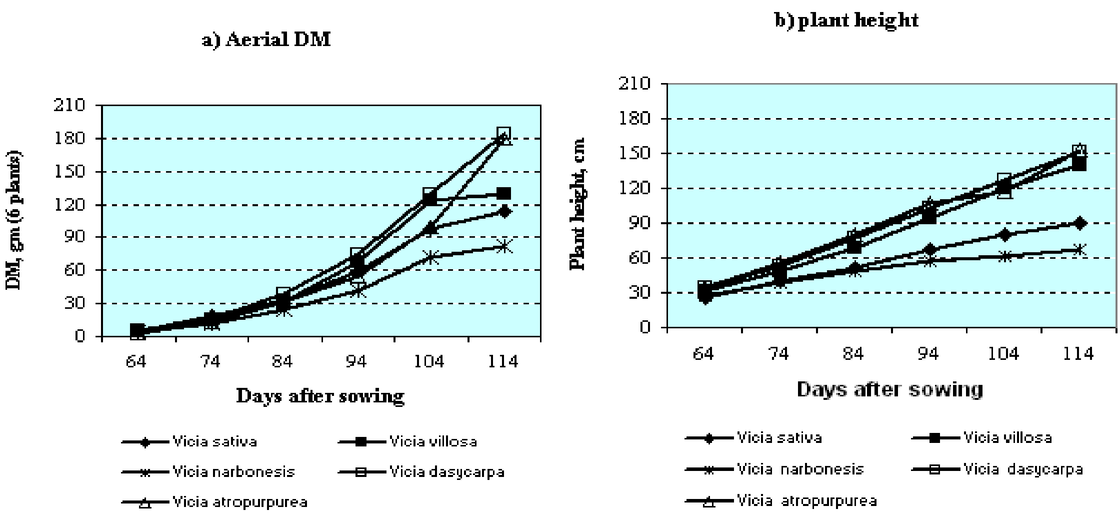

Figure 3. Mean aerial DM accumulation of all the species combined over locations

On the other hand, early maturing varieties could be sown in short rains to feed the livestock during feed shortage. 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. Getnet *et al*., (2003) also reported that early maturing 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 for grains. The tested vetch species and their accessions showed significant variation (P<0.05) in plant height at forage harvesting stage. In addition to genetic variability, soil fertility and environmental conditions could also contribute to the difference in height. The average plant height was higher at Ginchi compared to Holetta, which could be attributed to higher and extended rainfall and favorable growing conditions. Plant height for vetch species at forage harvest showed variation (P<0.05) at both locations (Table 4). 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 vetch species at both testing sites. Plant height for accessions of vetch at forage maturity showed significant (P<0.05) difference at both locations (Table 5). Branching/tillering performance is an important consideration during selection of crops for better forage yield and ground cover to reduce soil erosion. Like other agronomic traits, branching performance was also influenced by environmental and genetic factors. The number of branches at forage harvest for species showed significant (P<0.05) difference at both locations (Table 4). Number of branches at forage harvest ranged from 1.3 to 10.8 and 2.4 to 14.5 at Holetta and Ginchi respectively. *Vicia dasycarpa* and *Vicia villosa* gave the highest branches at Holetta and Ginchi respectively, while *Vicia narbonensis* gave the lowest branches at both locations. Accessions of vetches also showed significant (P<0.05) difference for branching performance at both locations (Table 5). All *Vicia narbonensis* accessions had significantly lower (P<0.05) branching performance than the remaining accessions at both locations, while accession 2565 (*V. villosa*) had comparatively higher branching among others.

Table 4. Least square means for days to forage harvest (days), plant height (cm) and number of branches of vetch species at Holetta and Ginchi

	Days to forage harvest□		Plant height□		Number of branches@	
Species	Holetta	Ginchi	Holetta	Ginchi	Holetta	Ginchi
Vicia sativa	96.1^{c}	107.9^{c}	87.1^{b}	102.6^{b}	8.3^{b}	10.0^{b}
Vicia villosa	112.2^{a}	117.4^{b}	138.3^{a}	155.2^{a}	10.1^{a}	14.5^{a}
Vicia narbonensis	83.3^{d}	96.8^{d}	55.2^{c}	44.3^{c}	1.3^{c}	2.4^{c}
Vicia dasycarpa	105.3^{b}	113.0^{b}	151.6^{a}	167.0^{a}	10.8^{a}	13.8^{ab}
Vicia atropurpurea	108.3^{a}	124.7^{a}	136.9^{a}	185.9^{a}	7.0^{b}	10.0^{b}
Mean	101.0	112.0	113.8	131.0	7.5	10.1
CV (%)	0.7	1.0	3.5	4.6	12.6	20.3
P-value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

Within column means with different superscripts differ significantly (P<0.05); □ □= log transformation, @ = Square root transformation

Vetch species have different growth habit and some of the species such as *Vicia villosa, Vicia dasycarpa* and *Vicia atropurpurea* have creeping growth habit while *Vicia narbonensis* has erect growth habit. Though *Vicia sativa* has an erect growth habit, creeping growth habit was observed due to good soil fertility of the experimental plots and favorable climatic conditions during experimental period. 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. Methods of forage legumes integration with food crops varied with growth habit of the forage legumes. For instance, species which has an erect growth habit is more compatible with small cereals in the intercropping/under-sowing systems while creeping or climbing growth habit has better compatibility with large cereals in the above integration systems. According to Getnet *et al.,* (2002), depending on the soil fertility condition, creeping or climbing type of vetch 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. Studies at Holetta also 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). Generally, for good compatibility, plant height and growth habit of forage legumes should be considered for optimum yield of companion crops without significant effect of one on the other.

Table 5. Average days to forage harvest (days), plant height (cm) and number of branches of vetch accessions grown at Holetta and Ginchi

		Days to forage harvest		Plant height		Number of branches@	
Species	Accessions	Holetta	Ginchi	Holetta	Ginchi	Holetta	Ginchi
Vicia sativa	64266	94.0[e]	103.7[ef]	96.3[c]	103.3[e]	7.1[de]	11.1[bc]
V. sativa	61904	92.7[e]	104.0[ef]	89.8[c]	102.5[e]	6.8[e]	12.6[bc]
V. sativa	61744	97.3[d]	112.3[cde]	84.8[c]	131.1[cd]	9.2[abcde]	10.9[bc]
V. sativa	61509	97.0[d]	110.0[cde]	85.3[c]	120.3[de]	9.7[abcde]	8.9[bc]
V. sativa	61039	99.3[d]	109.3[de]	73.7[cd]	100.3[e]	8.2[cde]	9.4[bc]
V. sativa	61212	96.0[de]	108.0[cde]	62.7[cd]	57.7[f]	8.6[bcde]	7.2[c]
V. villosa	2565	113.0[a]	112.7[cd]	139.1[ab]	133.1[cd]	12.6[a]	21.9[a]
V. villosa	2450	111.7[ab]	118.7[abc]	123.1[b]	144.0[bcd]	8.7[bcde]	11.1[bc]
V. villosa	2424	111.7[ab]	117.3[abcd]	148.2[a]	170.4[ab]	10.7[abc]	10.7[bc]
V. villosa	2438	112.0[a]	116.0[bcd]	119.3[b]	163.0[ab]	12.3[a]	12.1[bc]
V. villosa	2434	112.0[a]	126.0[a]	160.9[a]	157.4[abc]	9.0[bcde]	8.9[bc]
V. villosa	2446	112.7[a]	113.7[cd]	139.1[ab]	158.9[abc]	7.4[de]	22.4[a]
V. narbonensis	2384	80.7[g]	98.0[fg]	60.7[de]	47.6[f]	1.6[f]	2.8[d]
V. narbonensis	2387	82.0[g]	98.0[fg]	48.0[e]	38.5[f]	1.5[f]	2.3[d]
V. narbonensis	2376	88.7[f]	94.3[g]	54.8[de]	45.6[f]	1.2[f]	2.2[d]
V. narbonensis	2392	80.7[g]	96.7[fg]	53.2[de]	41.4[f]	1.2[f]	2.4[d]
V. narbonensis	2380	84.7[g]	97.0[fg]	59.5[de]	48.3[f]	1.2[f]	2.2[d]
V. dasycarpa	Namoi	105.3[c]	115.7[bcd]	149.2[a]	159.2[abc]	11.7[ab]	14.2[b]
V. dasycarpa	Lana	105.3[c]	110.3[cde]	153.9[a]	174.8[a]	9.9[abcd]	13.4[bc]
V. atropurpurea	Atropurpurea	108.3[bc]	124.7[ab]	136.9[ab]	185.9[a]	7.0[de]	10.0[bc]
	Mean	99.3	109.3	103.4	114.2	7.3	9.8
	CV (%)	0.5	0.9	13.1	13.4	11.0	16.6
	P-value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

Within column means with different superscripts differ significantly (P<0.05); = log transformation, @ = Square root transformation.

Proportions of Morphological Fractions and their Yields at Forage Harvest

Proportions of morphological fractions including leaf, stem, and green pod and flower in the dry matter basis of vetch species and their accessions were 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 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). The average proportions of leaf, stem, and green pod and flower and leaf to stem ratio were significantly (P<0.05) different among the species of vetch (Tables 6 and 10). 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. The highest leaf proportion was obtained from *Vicia narbonensis* followed by *Vicia sativa*, *Vicia atropurpurea*, *Vicia villosa* and *Vicia dasycarpa* at both locations. On the other hand, proportion of morphological fractions were also significantly ($P<0.05$) different among the accessions of vetch (Tables 7 and 11). Generally, short and early maturing species such as *Vicia narbonensis* and *Vicia sativa* gave the highest leaf proportion at forage harvest. Fekede (2004) also illustrated that short and early maturing varieties of oats had comparatively higher proportion of leaf than stem during the early stages. 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. For instance, *Vicia narbonensis* is morphologically similar to faba bean and hence branching performance was lower compared with other vetch species. 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. However, compared to grasses, legumes are in general superior in feeding value because they have higher content of protein and minerals and for identical values of digestibility; their voluntary intake is considerably higher due to the higher levels of soluble cell content and a quicker microbial access to cell walls, which result in a faster rate of digestion (Van Soest, 1994). Proportion of green pod and flower was lower compared with the others morphological fractions at forage harvest. Variation in green pod and flower proportion at each testing site could be due to variation in genetic traits such as branching performances and stage of maturity (phenology). 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. In general early maturing vetch species and their accessions produced higher proportion of green pod and flower than late maturing species and their accessions.

Dry matter 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 (Tables 8). The estimated yields of morphological fractions at forage harvesting stage of vetch species ranged from 0.51 to 1.46 t ha^{-1} for leaf DM yield; 0.70 to 3.50 t ha^{-1} for stem DM yield; and 0.17 to 0.90 t ha^{-1} for green pod and flower DM yield at Holetta, while 0.73 to 2.26 t ha^{-1} for leaf DM yield; 0.97 to 4.72 t ha^{-1} for stem DM yield; and 0.29 to 1.04 t ha^{-1} for green pod and flower DM yield at Ginchi. Though *Vicia narbonensis* gave the highest leaf proportion due to broad type leaf, 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. 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. Yields of morphological fractions of vetch accessions had significant (P<0.05) difference at both locations (Tables 9). Among vetch accessions, botanical fractions yield varied due to genetic and environmental variability in general and variation in maturity time and morphological fractions in particular. 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 promotion of early maturing oats varieties as preceding forage crops to chickpea/grass pea will be a sound strategy as it enables the smallholder to get additional benefit from the same plot of land within a season without disturbing the normal farming practice (Fekede, 2004).

Table 6. Least square means for proportions of leaf, stem and green pod and flower (%) of vetch species at Holetta and Ginchi

	Leaf		Stem[!]		Green pod and 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
Viciavillosa	25.2[cd]	25.5[b]	59.6[a]	61.9[a]	15.4[a]	12.6
Vicianarbonensis	36.7[a]	36.7[a]	51.1[b]	48.8[b]	12.1[bc]	14.5
Viciadasycarpa	23.0[d]	23.5[b]	63.5[a]	63.4[a]	14.1[ab]	13.1
Viciaatropurpurea	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 (%)	13.0	12.4	10.3	12.1	16.5	24.2
P-value	0.0001	0.0001	0.0002	0.0166	0.0002	0.4819

Within column means with different superscripts differ significantly (P<0.05); ! = Arcsine transformation.

Biomass Production Rate and Forage Yield

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-1 day-1 at Holetta and 15.4 to 63.2 kg ha-1 day-1 at Ginchi (Table 10). 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 vetch 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. Accessions of vetch was not significant (P>0.05) for biomass production rate at both locations (Table 11). Generally, the highest biomass production rate was recorded for accession 64266 (*V. sativa*), which had 60.4 and 86.3 kg ha-1 day-1 at Holetta and Ginchi respectively. On the other extreme, the lowest rate was recorded for atropurpurea (*V. atropurpurea*), which had

12.8 and 15.4 kg ha-1 day-1 at Holetta and Ginchi respectively. Among vetch species and their accessions, total dry biomass forage yield varied across the testing sites at forage harvesting stage. The highest total DM yield was obtained at Ginchi than Holetta. Accordingly, on average the species gave 33.6% more total herbage 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-1at Holetta and Ginchi respectively (Table 10). *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 (Chia, 1983). Fekede (2004) also reported that intermediate to late maturing oats varieties gave comparatively higher forage yield than the early maturing oats varieties. Total DM yield of vetch accessions also showed significant ($P<0.05$) difference at both locations (Table 11). 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 mean biomass yield was obtained on black soil (Ginchi) than red soil (Holetta) 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 in relatively higher biomass yield. Experimental finding had also shown that planting chickpea, lentil and faba bean on BBF resulted in grain yield increments compared to un-drained flat bed conditions (Getachew and Amare, 2004).

Table 7. Average proportions of leaf, stem and green pod and flower fractions (%) of vetch accessions grown at Holetta and Ginchi

		Leaf		Stem		Green pod and flower	
Species	Accessions	Holetta	Ginchi	Holetta	Ginchi	Holetta	Ginchi
Vicia sativa	64266	28.8^{defg}	35.2^{bcd}	51.4^{fgh}	51.3^{cd}	19.8^{a}	13.5^{abcde}
V. sativa	61904	27.0^{efgh}	36.4^{abcd}	56.1^{cdefg}	54.9^{c}	16.9^{ab}	8.7^{def}
V. sativa	61744	29.7^{def}	32.1^{cde}	51.3^{fgh}	50.0^{cd}	19.0^{ab}	17.9^{abc}
V. sativa	61509	26.2^{efghi}	30.2^{def}	57.1^{bcdef}	54.0^{c}	16.7^{ab}	15.8^{abcd}
V. sativa	61039	32.4^{bcde}	33.2^{bcde}	48.3^{ghi}	45.7^{de}	19.3^{a}	21.2^{a}
V. sativa	61212	30.5^{cdef}	42.1^{a}	52.4^{efgh}	54.2^{c}	17.1^{ab}	3.7^{f}
V. villosa	2565	28.2^{defgh}	29.0^{efg}	58.1^{bcdef}	61.2^{ab}	13.8^{abcd}	9.9^{def}
V. villosa	2450	24.7^{fgh}	25.1^{fg}	60.4^{abcde}	61.2^{ab}	14.9^{abc}	13.7^{abcde}
V. villosa	2424	22.2^{hi}	24.0^{fg}	61.1^{abcd}	62.9^{a}	16.8^{ab}	13.1^{bcde}
V. villosa	2438	24.3^{fgh}	27.5^{efg}	59.8^{bcde}	61.2^{ab}	16.0^{ab}	11.3^{cdef}
V. villosa	2434	23.0^{ghi}	24.1^{fg}	64.5^{ab}	61.4^{a}	12.5^{bcd}	14.5^{abcde}
V. villosa	2446	27.3^{efgh}	23.5^{g}	54.0^{defgh}	63.4^{a}	18.7^{ab}	13.2^{bcde}
V. narbonensis	2384	33.6^{bcd}	35.8^{bcd}	47.2^{hi}	46.4^{de}	19.2^{a}	17.8^{abc}
V. narbonensis	2387	35.8^{abc}	36.3^{abcd}	56.4^{bcdefg}	43.1^{e}	7.7^{de}	20.7^{ab}
V. narbonensis	2376	36.3^{abc}	38.9^{ab}	54.5^{defgh}	53.1^{c}	9.2^{cde}	8.0^{ef}
V. narbonensis	2392	38.3^{ab}	35.6^{bcd}	43.3^{i}	46.0^{de}	18.4^{ab}	18.4^{abc}
V. narbonensis	2380	39.8^{a}	36.9^{abc}	54.1^{defgh}	55.4^{bc}	6.1^{e}	7.7^{ef}
V. dasycarpa	Namoi	17.9^{i}	23.3^{g}	67.9^{a}	63.6^{a}	14.2^{abc}	13.1^{bcde}
V. dasycarpa	Lana	26.9^{efghi}	23.8^{g}	59.1^{bcdef}	63.2^{a}	14.0^{abcd}	13.0^{bcde}
V. atropurpurea	Atropurpurea	28.9^{defg}	28.8^{efg}	63.3^{abc}	63.6^{a}	7.7^{de}	7.6^{ef}
	Mean	29.1	31.1	56.0	55.8	14.9	13.1
	CV (%)	11.2	10.8	7.6	5.9	22.8	30.9
	P-value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002

Within column means with different superscripts differ significantly ($P<0.05$)

Table 8. Least square means for leaf DM, stem DM and green pod and flower DM yields (t ha^{-1}) of vetch species at Holetta and Ginchi Within column means with different superscripts differ significantly (P<0.05); $^{\Phi}$ = log transformation.

Species	Leaf DM$^{\Phi}$		Stem DM$^{\Phi}$		Pod and flower DM$^{\Phi}$	
	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	1.2	1.7	2.7	3.6	0.6	0.8
CV (%)	13.2	10.5	9.8	10.3	11.6	19.1
P-value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0003

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

Table 9. Average leaf DM, stem DM and green pod and flower DM yields (t ha^{-1}) of vetch accessions grown at Holetta and Ginchi

Species	Accessions	Leaf DM$^{\Phi}$		Stem DM$^{\Phi}$		Pod and flower DM $^{\Phi}$	
		Holetta	Ginchi	Holetta	Ginchi	Holetta	Ginchi
Vicia sativa	64266	1.61^{a}	2.31^{abc}	2.99^{bc}	3.35^{c}	1.05^{ab}	0.86^{abcde}
V. sativa	61904	1.61^{a}	2.04^{abcd}	3.34^{ab}	3.47^{bc}	1.01^{ab}	0.63^{cde}
V. sativa	61744	1.56^{a}	2.91^{a}	2.69^{bc}	4.54^{abc}	1.00^{ab}	1.59^{a}
V. sativa	61509	1.34^{ab}	2.33^{abc}	2.93^{bc}	4.22^{abc}	0.83^{abcd}	1.24^{ab}
V. sativa	61039	1.21^{ab}	2.73^{ab}	1.81^{cd}	3.85^{abc}	0.75^{abcd}	1.81^{a}
V. sativa	61212	1.40^{ab}	1.20^{de}	2.39^{bc}	1.54^{d}	0.78^{abcd}	0.11^{g}
V. villosa	2565	1.43^{ab}	1.57^{cd}	3.07^{bc}	3.32^{c}	0.74^{abcd}	0.54^{bcde}
V. villosa	2450	1.18^{ab}	1.94^{abcd}	2.83^{bc}	4.72^{abc}	0.68^{abcd}	1.06^{abc}
V. villosa	2424	1.65^{a}	2.08^{abc}	4.55^{a}	5.45^{a}	1.28^{a}	1.13^{ab}
V. villosa	2438	1.17^{ab}	2.34^{abc}	2.79^{bc}	5.28^{ab}	0.74^{abcd}	0.98^{abcd}
V. villosa	2434	1.59^{a}	1.96^{abcd}	4.53^{a}	4.98^{abc}	0.86^{abc}	1.17^{ab}
V. villosa	2446	1.65^{a}	1.68^{bcd}	3.20^{abc}	4.54^{abc}	1.11^{a}	0.94^{abcde}
V. narbonensis	2384	0.49^{cd}	0.78^{ef}	0.69^{d}	1.02^{d}	0.28^{bcdef}	0.41^{def}
V. narbonensis	2387	0.54^{cd}	0.68^{f}	0.84^{d}	0.80^{d}	0.12^{ef}	0.39^{ef}
V. narbonensis	2376	0.39^{d}	0.68^{f}	0.57^{d}	0.94^{d}	0.10^{f}	0.14^{g}
V. narbonensis	2392	0.56^{cd}	0.71^{f}	0.64^{d}	0.91^{d}	0.28^{def}	0.37^{ef}
V. narbonensis	2380	0.57^{cd}	0.79^{ef}	0.78^{d}	1.19^{d}	0.09^{fg}	0.17^{fg}
V. dasycarpa	Namoi	0.86^{bc}	1.70^{bcd}	3.28^{ab}	4.64^{abc}	0.69^{abcd}	0.96^{abcd}
V. dasycarpa	Lana	1.63^{a}	1.54^{cd}	3.60^{ab}	4.10^{abc}	0.85^{abc}	0.84^{abcde}
V. atropurpurea	Atropurpurea	1.46^{a}	2.10^{abc}	3.24^{abc}	4.52^{abc}	0.40^{abcd}	0.52^{bcde}
	Mean	1.2	1.7	2.5	3.4	0.7	0.8
	CV (%)	12.7	9.2	29.7	28.6	9.4	12.2
	P-value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

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

Table 10. Least square means for biomass production rate (kg ha^{-1} day^{-1}), total DM yield (t ha^{-1}) and leaf to stem ratio of vetch species at Holetta and Ginchi

Species	Biomass production rate$^{\Phi}$		Total DM yield$^{\Phi}$		Leaf to stem ratio	
	Holetta	Ginchi	Holetta	Ginchi	Holetta	Ginchi
Vicia sativa	47.3^{ab}	63.2^{a}	5.05^{a}	6.79^{a}	0.56^{b}	0.68^{b}
Vicia villosa	50.3^{a}	50.6^{a}	5.84^{a}	7.62^{a}	0.42^{c}	0.41^{c}
Vicia narbonensis	47.8^{ab}	61.7^{a}	1.39^{b}	1.99^{b}	0.73^{a}	0.76^{a}
Vicia dasycarpa	29.3^{bc}	40.7^{ab}	5.46^{a}	6.89^{a}	0.36^{c}	0.37^{c}
Vicia atropurpurea	12.8^{c}	15.4^{b}	5.09^{a}	7.14^{a}	0.46^{bc}	0.45^{c}
Mean	37.5	46.3	4.6	6.1	0.5	0.5
CV (%)	16.4	15.8	21.1	21.1	19.7	15.5
P-value	0.0037	0.0131	0.0001	0.0001	0.0001	0.0001

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

Correlations between Measured Traits

When one selects varieties for certain desired trait, there is a need to consider the relationships between various production traits to select varieties with most of the traits compromised (Getnet *et al.*, 2003). They also reported that this general relationships help to identify varieties that best fits to a specific purpose, with a reasonable forage yield, better quality and overall efficiency utilization. The linear correlation coefficients between the different agro-morphological traits estimated for different vetch accessions are illustrated in Table 12. Days to forage harvest showed a strong (P<0.001) positive correlation with plant height at forage harvest (r = 0.88), forage DM yield (r = 0.78), but negatively correlated (P<0.001) with leaf to stem ratio (r = -0.87). It was also negatively correlated (P>0.05) with biomass production rate (r = -0.34). Fekede (2004) also reported that days to maturity of forage correlated positively with plant height and herbage yield. Generally, early maturing vetch accessions had shorter plant height; faster biomass production rate; higher leaf to stem ratio; and lower DM yield than late and intermediate maturing vetch accessions. Plant height at forage harvest showed a significant (P<0.001) positive correlation with forage DM yield (r = 0.79), and leaf proportion (r = 0.35; P>0.05). It was negatively (P<0.001) correlated with leaf to stem ratio (r = -0.91), and biomass production rate (r = -0.41; P>0.05). Fekede (2004) also reported that plant height at forage harvest was positively and significantly correlated with herbage yield of oats varieties.

Table 11. Average biomass production rate (kg ha^{-1} day^{-1}), total DM yield (t ha^{-1}) and leaf to stem ratio of vetch accessions grown at Holetta and Ginchi

		Biomass production rate		Total DM yield$^{\Phi}$		Leaf to stem ratio	
Species	Accessions	Holetta	Ginchi	Holetta	Ginchi	Holetta	Ginchi
Vicia sativa	64266	60.4	86.3	5.65^{ab}	6.52^{ab}	0.56^{cdef}	0.69^{abc}
V. sativa	61904	46.9	63.1	5.96^{ab}	6.13^{b}	0.48^{efg}	0.68^{bc}
V. sativa	61744	53.5	75.5	5.25^{ab}	9.04^{a}	0.58^{bcde}	0.64^{bc}
V. sativa	61509	49.6	67.0	5.10^{ab}	7.79^{ab}	0.46^{efg}	0.56^{cd}
V. sativa	61039	28.5	32.3	3.76^{b}	8.38^{ab}	0.68^{bc}	0.73^{ab}
V. sativa	61212	44.7	55.2	4.57^{ab}	2.84^{c}	0.58^{bcde}	0.78^{ab}
V. villosa	2565	46.7	49.5	5.24^{ab}	5.44^{ab}	0.49^{efg}	0.48^{de}
V. villosa	2450	49.2	52.6	4.68^{ab}	7.73^{ab}	0.41^{fgh}	0.41^{de}
V. villosa	2424	53.7	60.7	7.48^{a}	8.66^{ab}	0.37^{gh}	0.38^{e}
V. villosa	2438	57.0	37.2	4.70^{ab}	8.60^{ab}	0.41^{fgh}	0.45^{de}
V. villosa	2434	45.3	55.7	6.98^{a}	8.11^{ab}	0.36^{gh}	0.39^{e}
V. villosa	2446	49.8	47.9	5.96^{ab}	7.16^{ab}	0.51^{defg}	0.37^{e}
V. narbonensis	2384	40.0	45.1	1.46^{c}	2.21^{c}	0.71^{bc}	0.77^{ab}
V. narbonensis	2387	64.2	73.9	1.49^{c}	1.87^{c}	0.66^{bcd}	0.84^{a}
V. narbonensis	2376	36.2	60.9	1.06^{c}	1.76^{c}	0.67^{bcd}	0.73^{ab}
V. narbonensis	2392	46.3	61.2	1.47^{c}	1.99^{c}	0.89^{a}	0.78^{ab}
V. narbonensis	2380	52.3	67.1	1.44^{c}	2.15^{c}	0.74^{b}	0.67^{bc}
V. dasycarpa	Namoi	28.3	31.3	4.83^{ab}	7.30^{ab}	0.27^{h}	0.37^{e}
V. dasycarpa	Lana	30.4	50.0	6.09^{ab}	6.48^{ab}	0.46^{efg}	0.38^{e}
V. atropurpurea	atropurpurea	12.78	15.4	5.09^{ab}	7.14^{ab}	0.46^{efg}	0.45^{de}
	Mean	44.8	54.4	4.4	5.9	0.5	0.6
	CV (%)	51.4	52.4	20.1	16.9	16.3	14.5
	P-value	0.6170	0.4393	0.0001	0.0001	0.0001	0.0001

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

Generally, taller vetch accessions had lower leaf to stem ratio; higher DM yield; and slower biomass production rate than shorter accessions of vetch. Getnet *et al*., (2003) also reported that taller and late maturing oats varieties had higher forage yield. Biomass production rate showed a significant ($P<0.01$) negative correlation with the proportion of leaf ($r = -0.54$), but non-significant ($P>0.05$) positive correlation with leaf to stem ratio ($r = 0.28$). Forage DM yield had weak positive correlation ($r= 0.01$; $P>0.05$) with biomass production rate. It was observed that fast growing accessions had higher leaf to stem ratio, but lower forage DM yield than slow growing ones. The proportion of leaf had non-significant positive correlation with forage DM yield ($r = 0.07$), however, the proportion of stem had non-significant negative correlation with forage DM yield ($r = -0.17$). Leafiness of vetch accessions had a positive relationship with forage DM yield whereas stemmy accessions had negative correlation with forage DM yield.

Table 12. Spearman rank-order correlation coefficients among agro-morphological traits of different accessions of vetch at Holetta and Ginchi

Parameters	DFH	PHFH	BPR	LP	SP	LSR
PHFH	0.88***					
BPR	-0.34	-0.41				
LP	0.24	0.35	-0.54**			
SP	-0.22	-0.31	0.25	-0.80***		
LSR	-0.87***	-0.91***	0.28	-0.26	0.25	
FDMY	0.78***	0.79***	0.01	0.07	-0.17	-0.76***

DFH- Days to forage harvesting (days); **PHFH**- plant height at forage harvesting (cm); **BPR**- Biomass production rate (kg ha^{-1} day^{-1}); **LP**- Leaf proportion (%); **SP**- Stem proportion (%); **LSR**- Leaf to stem ratio; **FDMY**- Forage dry matter yield (t ha^{-1})

CONCLUSIONS

The different vetch species and their accessions in this study showed variations in most measured agro-morphological traits at both testing sites due to differences in genetic and environmental factors. Longer days to emerge, higher seedling count and lower vigorous growth were observed at Ginchi than Holetta during the early stage of growth. Relatively higher aerial DM accumulations, branching performance and plant height with faster growth rate were recorded at Ginchi than Holetta over the sampling period. The growth habit differed among the species of vetch and hence creeping growth habit is the characteristic of *Vicia dasycarpa*, *Vicia villosa* and *Vicia atropurpurea*, whereas *Vicia narbonensis* and *Vicia sativa* have erect growth habit, however, *Vicia sativa* lodges on fertile soils and has the tendency of creeping.

Mean leaf proportion and leaf to stem ratio were higher at Ginchi, whereas proportions of stem and green pod and flower were higher at Holetta. Short and early maturing vetch species had higher leaf to stem ratio than tall and intermediate to late maturing vetch species at forage harvesting stage. *Vicia villosa* and *Vicia sativa* had the highest biomass production rate at Holetta and Ginchi respectively. Vetch species which have erect growth habit and shorter plant height showed fast biomass production rate and lower number of branches 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 both locations at forage harvesting stage. Late maturing vetch species gave higher forage DM and its morphological fraction yields than early maturing vetch species at both locations.

Forage DM yield was positively correlated with days to forage harvest, plant height at forage harvest, biomass production rate and leaf proportion. However, it was negatively correlated with leaf to stem ratio and stem proportion. Generally, vetch species and their accessions have different growth features and phenology. These differences are important to select the type of companion crops (food and forage) and methods of integration to improve yields of both companion crops without significant effect of one on the other. Compatible crops can give higher yields per unit area when proper management methods were done and selection of crops is well performed during integration.

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