Vol-3, Issue-4 PP. 241-249 ISSN: 2394-5788

GLOBAL JOURNAL OF ADVANCED RESEARCH
(Scholarly Peer Review Publishing System)

GROWTH DYNAMICS IN VETCH SPECIES AND THEIR ACCESSIONS UNDER NITOSOL AND VERTISOL CONDITIONS IN THE CENTRAL HIGHLANDS OF ETHIOPIA

Gezahagn Kebede
Ethiopian Institute of Agricultural Research, Holetta Research Center
P.O.Box, 31, Holetta,
Ethiopia
gezk2007@yahoo.co.uk

ABSTRACT

Twenty accessions of vetch species were evaluated for their growth dynamics under nitosol (Holetta) and vertisol (Ginchi) conditions of Ethiopia. The study was conducted in randomized complete block design with three replications. Data on dynamics of shoot and root dry matter accumulations, plant height and branch number over the sampling periods were collected by sampling 6 plants in every 10 days starting from 64 days after sowing and analyzed using the general linear model procedures of SAS and duncan multiple range test at 5% significance was used for mean comparisons. The result showed that the rates of shoot and root dry matter accumulations, plant height and branch number were different ($P<0.05$) for vetch species and their accessions at both locations over the sampling periods. Among the vetch species, *Vicia dasycarpa* accumulated the highest shoot dry matter in fastest rate followed by *Vicia atropurpurea*, *Vicia villosa*, *Vicia sativa* and *Vicia narbonensis* over the sampling periods. The accessions of vetch species had relatively lower and similar shoot and root dry matter, plant height and branch number at the early stage of growth at both locations. But at the subsequent sampling periods, the rate of measured growth parameters was different at both locations. Generally, higher shoot and root dry matter accumulations, plant height and branch number with faster rate were recorded at Ginchi than Holetta due to variations in soil types, temperature and amount of rainfall in both testing sites.

Keywords: accessions, branch number, dry matter accumulation, plant height, vetch species.

1. INTRODUCTION

Herbage accumulation defined as the change in mass between successive measurements and as the difference between herbage growth and disappearance (Hodgson, 1979). Several methods to understand herbage accumulation rate have been explored in order to describe and predict accumulation in pastures (Parsons *et al.*, 1988). The most common approach to measure herbage accumulation is based on herbage mass at two or more consecutive harvest dates and calculating the average change in mass per unit of time. The decrease in rate of herbage accumulation can be a result of senescence or development (Thornley and France, 2007) of the population in question. The growth processes of each organ depend on cell division and elongation to provide the ultrastructure for plant tissue development and biomass accumulation. The elongated cells then differentiate to form specific organs and accommodate associated physiological functions. Interactions among leaf, tiller and root meristems are coordinated to assure the orderly development of the plant.

Photosynthesis, respiration and translocation contribute to the increase in dry matter while growth in area results from the division and expansion of cells followed by their shrinkage or death (Atkinson and Porter, 1996). The complex responses of rooting to soil physical, environmental and interaction with external factors as a result of root to shoot relationship are well known (Betz *et al.,* 1998). Shoot perceives external factors and send signal to root system, which in turn respond in several ways to adjust carbon allocation and its growth (Baker *et al.*, 1992). Water, oxygen, temperature, and mechanical impedance all affect directly plant growth, on the plant different developing stages, from seedling emergence to root penetration. Of the environmental factors that affect growth, dry matter (DM) accumulation and its partitioning, soil and the atmospheric environment are the most important. In a production system, stresses such as drought, water logging, high and low temperatures affect crop growth and production which are further influenced by biotic factors and management (Huda and Maiti, 1997). Knowledge of root biomass dynamics is fundamental to improving our understanding of carbon allocation and storage in terrestrial ecosystems (Cairns *et al.,* 1997). One approach to gaining a greater understanding of root biomass distribution has been to explore the relationship between root biomass and shoot biomass, most commonly through the root : shoot ratio. The allocation of dry matter to roots changes during their life cycle and with growing conditions. Typically, relatively more assimilates are channeled to roots during early growth but, as development proceeds, the growing reproductive structures come to dominate and the amount of assimilate translocated to roots decreases.

Currently, with the rapid increase in human population and increasing demand of food, grazing lands are steadily shrinking being converted to arable lands and availability of adequate feeds has become a major bottleneck to increased livestock production in Ethiopia. Growing forages on cultivated land is a new concept for most farmers and some farmers also fear that forage legumes may become weeds, whereby farmers give higher priority for crop production. Integration of forage legumes into the cereal-based cropping system through different methods are one of the strategic interventions for optimizing the productivity of a given land use system. But, before integration of forage legumes with food crops, study on growth dynamics of forage legumes is vital for good compatibility to improve yields of companion crops without significant effect of one on the other. However, there is no wide assessments have been done on growth dynamics of vetch species and their accessions grown in different soil types. Therefore, this study was designed to evaluate the growth dynamics of vetch species and their accessions under nitosol (Holetta) and vertisol (Ginchi) conditions in Ethiopia.

2. MATERIALS AND METHODS

2.1 Descriptions of the study sites

The experiment was conducted at Holetta Agricultural Research Center (HARC) and Ginchi sub center during the main cropping season under rain fed condition. The sites have a bimodal rainfall pattern, with the main rain from June to September and short rain from March to May. The farming system of the study areas is mixed crop livestock production system. Descriptions of the test environments are indicated in Table 1.

2.2 Experimental design and treatments

The study was executed using 20 accessions selected from five vetch species. 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 and currently the materials are available at HARC. Most of the accessions of vetch species were selected on the basis of their adaptation to the central highlands of Ethiopia in the previous screening trials. The experimental fields were prepared following the recommended tillage practice (ploughing with a mould-board plough during the short rainy season in March followed by harrowing once using a disc harrow in early May and a slight hoeing to loosen the soil) 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. A spacing of one meter was used between plots and between blocks. The two rows next to the guard rows were used for destructive sampling to assess the dynamics in shoot and root DM accumulations, plant height and branch number over the sampling periods.

Based on experimental design, each treatment was assigned randomly to the experimental units within a block. The materials were sown according to their recommended seeding rates: 25 kg ha^{-1} for *Vicia villosa*, *Vicia dasycarpa* and *Vicia atropurpurea*; 30 kg ha^{-1} for *Vicia sativa* and 75 kg ha^{-1} for *Vicia narbonensis*. At sowing, 100 kg ha^{-1} diamonium phosphate (DAP) fertilizer was uniformly applied for all treatments at both locations. The first hand weeding was made thirty days after crop emergence (40 days after sowing/DAS) and the second weeding was done thirty days after the first weeding to minimize yield reduction due to competition for major growth resources such as nutrients, water and light. Generally, maximum cares (presence of pest and disease, drain excess water, prevent from animals etc.) were taken in the experimental plots to reduce the possible yield limiting factors which could affect the performance of yield potential of the accessions of the vetch species.

Table 1: Descriptions of the test locations for geographical position and physico-chemical properties of the soils

Parameters	Holetta	Ginchi
Latitude	9° 00'N	9° 02'N
Longitude	38° 30'E	38.12° E
Altitude (masl)	2400	2200
Distance from Addis Ababa (km)	29	75
Annual Rainfall (mm)	1055	1095
Daily minimum temperature (°C)	6.1	8.4
Daily maximum temperature (°C)	22.2	24.6
Soil type	Nitosol	Vertisol
Textural class	Clay	Clay
pH(1:1 H_2o)	5.24	6.5
Total organic matter (%)	1.80	1.3
Total nitrogen (%)	0.17	0.13
Available phosphorous (ppm)	4.55	16.5

2.3 Data collection

In order to assess the dynamics of shoot and root dry matter (DM) accumulation over the sampling periods, six plants were randomly taken from two rows next to the guard rows of each plot using destructive sampling method in every 10 days beginning from 64 to 114 DAS (Getnet, 1999). The plants were uprooted and the shoot and root parts of the plants were separated manually. Fresh biomass yield of the shoot and root parts were separately weighed and the samples were oven-dried at 65°c for 72 hours to determine the dynamics of the shoot and root dry matter (DM) accumulations during the sampling periods. Six stretched plant heights were taken from the ground to the tip of the plants just prior to each sampling period and was regarded as another component of growth. Six such measurements (dynamics in shoot and root DM accumulations, plant height and branch number) were made during the sampling periods.

2.4 Statistical analysis

Analysis of variance (ANOVA) procedures of SAS general linear model (GLM) was used to compare treatment means (SAS, 2002). Duncan Multiple Range Test (DMRT) at 5% significance was used for comparison of means. The data was analyzed using the following model. $Y_{ijk} = \mu + T_i + L_j + (TL)_{ij} + B_{k(j)} + e_{ijk}$ Where, Y_{ijk} = measured response of treatment i in block k of location j; μ = grand mean; T_i = effect of treatment i; L_j = effect of location j; TL= treatment and location interaction; $B_{k(j)}$ = effect of block k in location j; e_{ijk} = random error effect of treatment i in block k of location j.

3. RESULTS AND DISCUSSION

3.1 Dynamics in shoot dry matter (DM) accumulation and plant height

Dynamics in shoot DM and plant height of the accessions of vetch species over the sampling periods were evaluated by sampling 6 plants in every 10 days starting from 64 days after sowing (DAS). Mean shoot DM accumulation and growth in height of 20 accessions of vetch species grown at Holetta (nitosol) and Ginchi (vertisol) are presented in Figure 1. The result showed that the rate of shoot DM accumulation and growth in height during the initial sampling were generally low, but for other subsequent samplings, the rate of shoot DM accumulation and growth in height increased with faster rates at both locations. The rate of shoot DM accumulation and growth in height were similar during the initial stage of growth at both locations. However, after the second sampling (74 DAS), shoot DM accumulation varied widely in both testing sites. Consequently, higher shoot DM was obtained at Ginchi (vertisol) than Holetta (nitosol) over the sampling periods. Unlike shoot DM accumulation, growth in height was less affected by locations over the sampling periods. However, after the third sampling (84 DAS), growth in height relatively varied in both testing sites and higher plant height was recorded at Ginchi during the sampling periods. Generally, higher rate of shoot DM accumulation and growth in height were obtained at Ginchi (vertisol) than Holetta (nitosol) over the sampling periods. The shoot to root biomass ratio changes during ontogeny, generally becoming high as the plant approaches flowering, and stabilizing after flowering (Zobel, 1986). Shoot-to-root ratios of common bean, rice, wheat, and cowpea increased as plants advanced in age (Fageria, 1992). Increases in shoot-to-root ratios indicate that shoots have a higher priority for photosynthates accumulation than roots. If shoot–root ratios decrease with time, roots have preferential utilization of photosynthates under the existing plant growth conditions. A relatively high conservation of photoassimilates in shoots may increase the plant's photosynthetic leaf area while decreasing root biomass and the plant's capacity for water and nutrient uptake (Werf, 1996).

The rate of shoot DM accumulation and growth in height of vetch species were different (P<0.05) at both locations over the sampling periods. However, shoot DM at the first (64 DAS) and fourth (94 DAS) samplings at Holetta (nitosol) and third (74 DAS) sampling at Ginchi (vertisol) were not significantly different. On the other hand, shoot DM and plant height for subsequent samplings of each species was different (P<0.05) at both locations. Mean shoot DM accumulation of all species combined over locations is presented in Figure 2a. The result revealed that there was an increasing trend of shoot DM accumulation for all species over the sampling periods. This may be related to an increase in branching and leaf area that resulted in higher shoot DM at the later stage of samplings. Average accumulations of shoot DM for all species of vetch were 3.9, 14.6, 31.9, 59.5, 104.4 and 137.9 g at each sampling period.

Between the first two initial samplings, higher and faster shoot DM was obtained from all species than the other subsequent samplings and the increments ranged from 206 to 482 % during the sampling period. However, the higher and lower increments were recorded for *Vicia atropurpurea* and *Vicia narbonensis* respectively, during the first two subsequent samplings. Fekede (2004) also reported that the rate of shoot DM accumulation for 20 Oats varieties were higher between the initial two samplings (between 34 and 49 DAS). Though the first three subsequent samplings showed lower and similar shoot DM accumulations, the rate and amount of shoot DM accumulations varied largely to other subsequent samplings. Over the sampling periods, *Vicia dasycarpa* accumulated the highest and fastest shoot DM accumulation followed by *Vicia atropurpurea*, *Vicia villosa*, *Vicia sativa* and *Vicia narbonensis*. However, until the fifth (104 DAS) samplings, *Vicia villosa* gave higher shoot DM next to *Vicia dasycarpa* but after fifth samplings *Vicia atropurpurea* gave higher shoot DM than *Vicia villosa*.

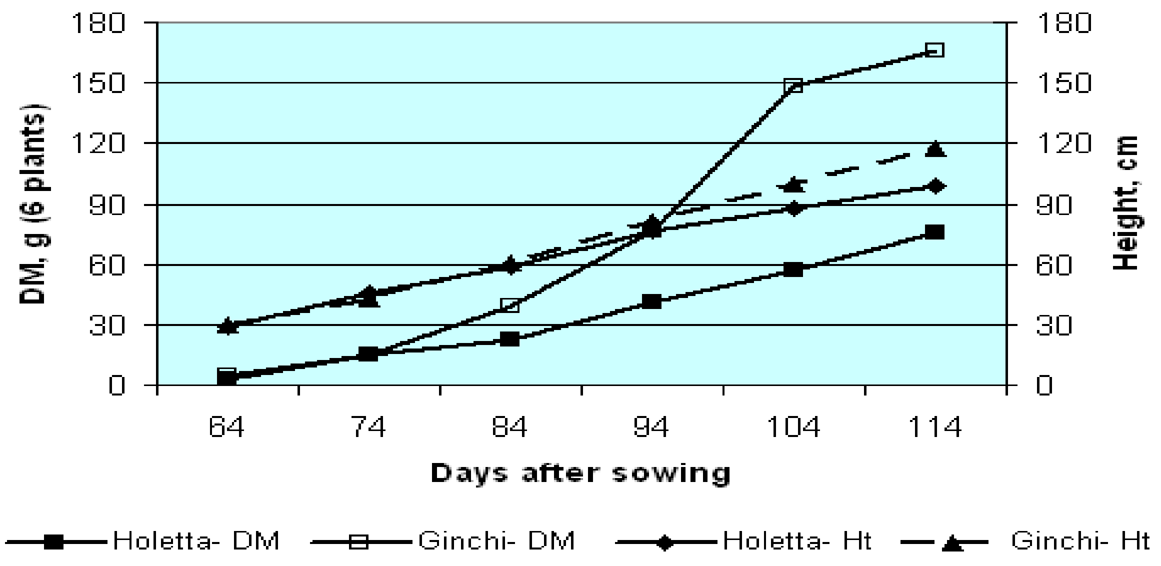


Fig.1: Mean shoot DM accumulation and plant height of vetch species grown at Holetta (nitosol) and Ginchi (vertisol) testing sites.

On the other hand, plant height among the species showed significant (P<0.05) difference during each sampling period and ranged from 30.8 to 108.9 and 31.2 to 131.2 cm at Holetta (nitosol) and Ginchi (vertisol) respectively. Mean plant height of five vetch species combined over locations is presented in Figure 2b. At the initial stage of growth, *Vicia narbonensis* and *Vicia sativa* had relatively similar and shorter plant height than the other species but *Vicia sativa* had relatively taller than *Vicia narbonensis* at the later stage of samplings. Generally, *Vicia atropurpurea* was taller at each sampling period except the fifth sampling followed by *Vicia dasycarpa*, and *Vicia villosa* over the sampling periods. 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.

Shoot DM accumulations among vetch accessions at each sampling was different (P<0.05) except at the fourth and third samplings at Holetta (nitosol) and Ginchi (vertisol) respectively. Moreover, the subsequent samplings for each accessions also showed significant difference at both locations. The twenty accessions of vetch species had relatively lower and similar shoot DM at the early stage of growth at both locations. But at the subsequent sampling periods, the rate of shoot DM accumulation was different at both locations. At Holetta (nitosol), shoot DM accumulated by *Vicia sativa* accessions 61509 and 61039 was higher and lower respectively. At Ginchi (vertisol), accession 61744 and 61039 accumulated the highest and lowest shoot DM respectively. Generally, accession 61039 accumulated the lowest shoot DM at both locations, while 61509 and 61744 accumulated the highest shoot DM at Holetta (nitosol) and Ginchi (vertisol) respectively. At Holetta (nitosol), accumulation of shoot DM by *Vicia villosa* accessions 2424 and 2438 was faster and slower respectively. At Ginchi (vertisol), *Vicia villosa* accessions 2565 and 2438 accumulated the highest and lowest shoot DM respectively. *Vicia narbonensis* accessions 2380 and 2376 accumulated the highest shoot DM at Holetta (nitosol) and Ginchi (vertisol) respectively. *Vicia dasycarpa* accessions Namoi and Lana accumulated the highest shoot DM over the sampling periods at Holetta (nitosol) and Ginchi (vertisol) respectively. Growth trend of *Vicia atropurpurea* accession was faster at Ginchi (vertisol) than Holetta (nitosol) conditions.

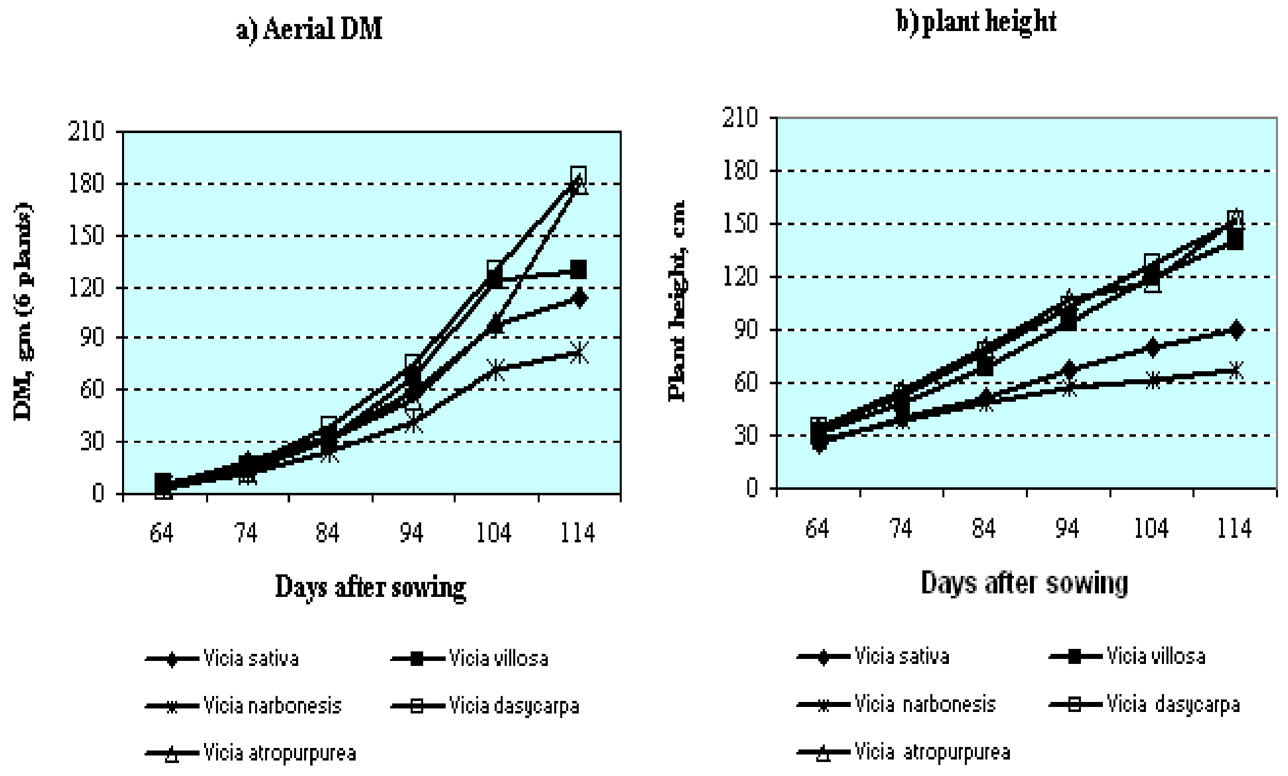
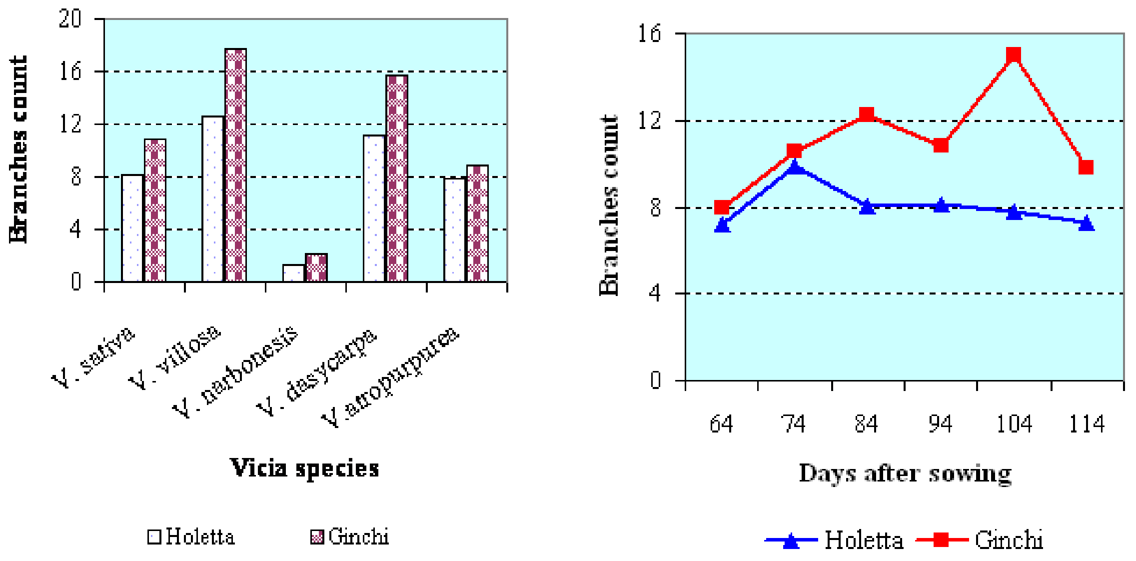


Fig. 2: Mean shoot/aerial DM accumulation (a) and plant height (b) of vetch species.

Generally, species and accessions 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. These differences are advantageous for selecting compatible crops and the type of appropriate integration method for maximum production. The difference in growth rates in both 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 flat bed conditions. Research reports also indicated that crops planted on BBF or RF produced superior grain and straw yields compared to those planted on flat seed-beds (Abate *et al*., 1993).

3.2 Dynamics in branch number over the sampling periods

Number of branches for species showed significant (P<0.05) difference during each sampling period at both locations. Mean number of branches for each species during the sampling periods at both locations is shown in Figure 3a. The number of branches for all species at each sampling period ranged from 1.4 to 12.5 and 2.1 to 17.7 at Holetta (nitosol) and Ginchi (vertisol) respectively. The result showed that 11.6 to 53.5% more number of branches was obtained from Ginchi (vertisol) over the sampling periods. Moreover, mean number of branches at each sampling period was different between Holetta (nitosol) and Ginchi (vertisol). Higher number of branches was recorded for *Vicia villosa* followed by *Vicia dasycarpa*, *Vicia sativa*, *Vicia atropurpurea* and *Vicia narbonensis* at both locations. Generally, higher number of branches counted at Ginchi (vertisol) than Holetta (nitosol) for all species over the sampling periods.



(a) **(b)**

Fig. 3: Mean number of branches for the species tested (a) and the trend of branch counts over the sampling periods (b) at Holetta (nitosol) and Ginchi (vertisol) testing sites.

Number of branches for accessions of vetch species at each sampling period also showed significant (P<0.05) difference at both locations. Mean number of branches for all accessions of vetch species at each sampling period is indicated in Figure 3b. The result revealed that mean number of branches for all accessions ranged from 7.2 to 9.9 and 8.0 to 15.0 over the sampling periods at Holetta (nitosol) and Ginchi (vertisol) respectively. Number of branch increment at Ginchi (vertisol) over Holetta (nitosol) ranged from 6.7 to 92.8 % over the sampling periods. Generally, mean number of branches of all accessions at Ginchi (vertisol) was higher than Holetta (nitosol) at each sampling period, and higher number of branches were recorded at sampling period two (74 DAS) and five (104 DAS) at Holetta (nitosol) and Ginchi (vertisol) respectively.

3.3 Dynamics in root DM accumulation over the sampling periods

Root DM accumulation among the species was different at both locations. The highest rate of root DM accumulation was recorded between the forth (94 DAS) and fifth (104 DAS) samplings and between the first (64 DAS) and second (74 DAS) samplings at Holetta (nitosol) and Ginchi (vertisol) respectively. Mean root DM accumulation for each species over the sampling periods at both locations is indicated in Figure 4a. The rate of root DM accumulation for each species over the sampling periods was significant (P<0.05) at both locations. Mean root DM accumulation over the sampling periods ranged from 1.2 to 1.7 gm and 1.7 to 3.7 gm at Holetta (nitosol) and Ginchi (vertisol) respectively. Higher root DM accumulation at Holetta (nitosol) was recorded for *Vicia narbonensis* followed by *Vicia dasycarpa*, *Vicia atropurpurea*, *Vicia villosa* and *Vicia sativa* over the sampling periods. Similarly, at Ginchi (vertisol), *Vicia narbonensis* gave higher root DM followed by *Vicia dasycarpa*, *Vicia villosa*, *Vicia sativa* and *Vicia atropurpurea*. Generally, root DM accumulation was higher at Ginchi (vertisol) than Holetta (nitosol) for all species.

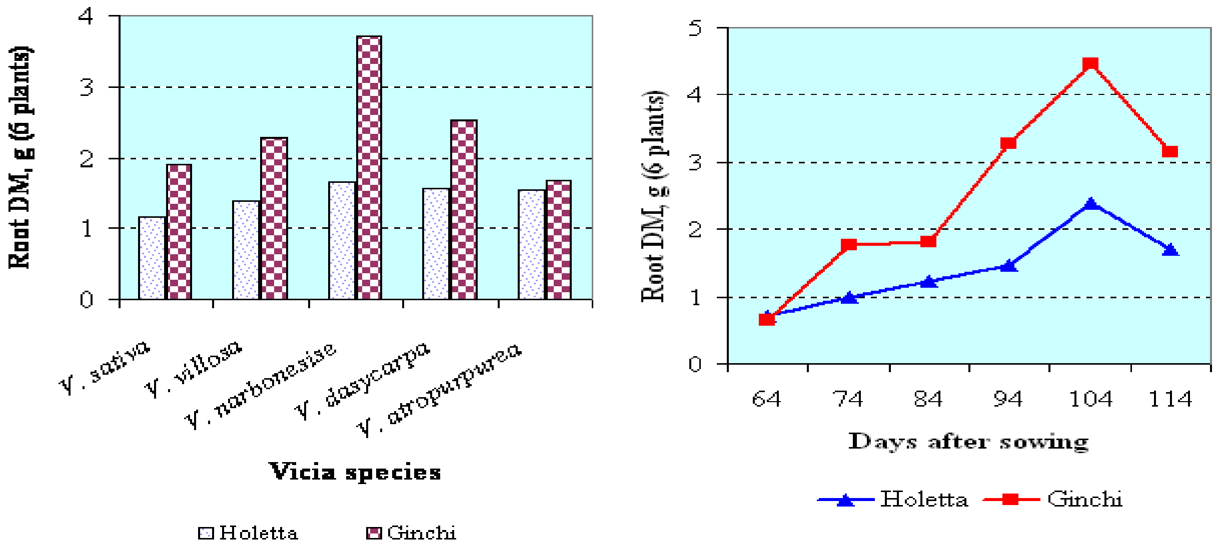


Fig. 4: Mean root DM accumulation for the species tested over the sampling periods (a) and for all accession at each sampling period (b) at Holetta and Ginchi testing sites.

Mean root DM accumulation for all accessions of vetch species at each sampling period is shown in Figure 4b. The lower and higher root DM accumulation was obtained from the first (64 DAS) and fifth (104 DAS) samplings respectively at both locations. Like shoot DM, root DM accumulation rate was higher between the first two samplings than the other subsequent samplings at Ginchi (vertisol), but between fourth (94 DAS) and fifth (104 DAS) sampling gave higher at Holetta (nitosol). This variation for high rate of root DM accumulation for accessions could be due to the difference in soil temperature and soil structure over the sampling periods. Lower soil temperature at the initial stage of growth and cracking effect of the soil at the end of the sampling period could cause lower root DM accumulation at Holetta (nitosol) and Ginchi (vertisol) respectively. Accordingly, more root DM accumulated after the mid of the samplings (between 94 and 104 DAS) at Holetta (nitosol) due to relatively warmer soil temperature and between the two initial samplings (between 64 and 74 DAS) at Ginchi (vertisol) due to good soil structure (no cracking due to moisture availability) at the sampling periods. Root DM accumulation for subsequent samplings of each accessions showed significant ($P<0.05$) difference at both locations. Generally, root DM accumulation was higher at Ginchi (vertisol) than Holetta (nitosol) except the first sampling and the increments at Ginchi (vertisol) over Holetta (nitosol) ranged from 49 to 123% over the sampling periods. Generally, the shoot and root DM accumulation had a positive correlation over the sampling periods. However, at the end of the sampling period, the root DM decreased due to pod formation which is a strong sink to compete for assimilates. The high root DM accumulation can be an advantage for better nitrogen fixation of forage legumes.

The root DM accumulation among the accessions of vetch species were different during each sampling at both locations. The rate of mean root DM accumulation for all accessions showed an increasing trend for subsequent samplings at both locations but the rate has decreased after fifth sampling (104 DAS). This could be due to transportation of more assimilates to the flower and pod parts of the plant than the root, because flowers and pods are strong sinks than the roots at flowering and pod formation stages. Singh *et al*., (2004) reported that the decline in leaf and stem weight at the later reproductive phase and maturity resulted in translocation of per-anthesis assimilates stored in these plant parts to the developing grains in wheat. In contrast to shoot, dry matter partitioning in roots is high during the seedling stages of the crop growth and steadily declines throughout development (Evans and Wardlaw, 1976). Other study also indicated that root development varies with stages of plant growth and development (Fageria *et al.*, 2006). The slow increase in root DM weight early in the growth cycle may be associated with low translocation of photosynthetic materials due to low leaf area (Fageria, 2007). When there is a low amount of photosynthetic product, a major part goes to the shoot, and very little is translocated to the roots (Fageria, 1992). Partitioning of photosynthates and their effects on DM distribution is influenced by several environmental factors such as low temperature, drought and mineral nutrient deficiency (Wardlaw, 1990). The mineral nutrients, phosphorus and nitrogen exerted pronounced influences on photosynthates and DM partitioning between shoots and roots (Costa *et al.*, 2002). Champigny and Talouizte (1981) reported that under nitrogen deprivation, translocation of photoassimilates from shoots to roots increased because of increased sink strength of roots compared to shoot sinks. Thus, roots become more competitive for photosynthates than shoots, which leads to higher export of carbohydrates to roots with correspondingly lower shoot-root ratios (Rufty *et al.*, 1993).

4. CONCLUSION

The tested vetch species and their accessions showed variations in their shoot and root DM accumulations, branching performance and plant height over the sampling periods at both locations. Relatively higher shoot DM accumulation, branching performance and plant height with faster rate were recorded at Ginchi than Holetta over the sampling periods. When compared the two locations, shoot DM accumulation for most species and their accessions varied widely after the second (74 DAS) samplings. However, the differences in plant height at both locations was not considerable over the sampling periods.

5. ACKNOWLEDGEMENTS

The author is grateful for financial support provided by the livestock research process of Holetta Agricultural Research Center (HARC) to undertake the experiment. My special gratitude goes to forage and forage seed research commodity colleagues at HARC for their technical and material support throughout the entire work.

6. REFERENCES

[1] Abate Tedla, M.A. Mohamed-Saleem, Tekalign Mamo, Alemu Tadesse and Miiressa Dufera. 1993. Grain, fodder, and residue management. Pp. 103-137. In: Tekalign Mamo, Abiya Astatke, K.L. Srivastava and Asgelil Dibabe (eds.). Improved management of vertisol for sustainabl crop-livestock production in the Ethiopian highlands. The joint vertisol project, Addis Ababa, Ethiopia.

[2] Atkinson, D. and J.R. Porter. 1996. Temperature, plant development and crop yields. Trends in Plant Science 1: 119-124.

[3] Baker, J.M., J.M. Wraith, and F.N. Dalton. 1992. Root function in water transport, p. 53-72, *In* J. L. HATFIELD and B. A. STEWART, eds. Limitations to plant root growth, Vol. 19. Springer-Verlag, Ney York.

[4] Betz, C.L., R.R. Allmaras, S.M. Copeland, and G.W. Randal. 1998. Least limiting water range: traffic and long term tillage influences in a Webster soil. Soil Science Society of American Journal 63:1384-1393.

[5] Cairns MA, Brown S, Helmer EH. 1997. Root biomass allocation in the world's upland forests. Oecologia, 111, 1–11.

[6] Champigny, M. L., and Talouizte, A. 1981. Photosynthate distribution and metabolic fate in relation to nitrogen metabolism in wheat seedlings. In "Photosynthesis: IV. Regulation of Carbon Metabolism" (G. Akoyunoglou, Ed.), pp. 645–652. Balban International Science Services, Philadelphia, PA.

[7] Costa, C., Dwyer, L. M., Zhou, X., Dutilleul, P., Hamel, C., Reid, L. M., and Smith, D. L. 2002. Root morphology of contrasting maize genotypes. Agron. J. 94, 96–101.

[8] Evans, L. T., and Wardlaw, L. F. 1976. Aspects of the comparative physiology of grain yield in cereals. Adv. Agron. 28, 301–359.

[9] Fageria, N. K. 1992. Maximizing Crop Yields. Marcel Dekker, New York.

[10] Fageria, N. K. 2007. Yield physiology of rice. J. Plant Nutr. 30, 843–879.

[11] Fageria, N. K., Baligar, V. C., and Clark, R. B. 2006. Physiology of Crop Production. The Howarth Press, New York.

[12] Fekede Feyissa. 2004. Evaluation of potential forage production qualities of selected oats (*Avena sativa* L.) genotypes. M.Sc. Thesis. Alemaya University of Agriculture, Ethiopia.

[13] Getachew Agegnehu, Abraham Feyissa, Gemechu Keneni and Mussa Jarso. 2007. Chickpea varietal responses to drainage on vertisol of Ginchi highlands of Ethiopia. Ethiopian Society of Soil Science, Ethiopian Journal of Natural Resources. (2): 191-207.

[14] Getnet Assefa. 1999. Feed resource assessment and evaluation of forage yield, quality and intake of oats and vetches grown in the highlands of Ethiopia. M.Sc. Thesis. Swedish University of agricultural science. Uppsala. Pp.1-19.

[15] Hodgson, J. 1979. Nomenclature and definitions in grazing studies. Grass Forage Sci. 34:11-17.

[16] Huda, A.K.S. and R.K. Maiti. 1997. Role of climatic factors on bean growth and development under abiotic stress factors. In: R. K. Maiti, (ed). *Phaseolus spp*. Bean Science. Enfield: Science Publishers Inc.

[17] Parsons, A.J., I.R. Johnson and A. Harvey. 1988. Use of a model to optimize the interaction between the frequency and severity of intermittent defoliation and to provide a fundamental comparison of the continuous and intermittent defoliation of grass. Grass Forage Sci. 43:49-59.

[18] Rufty, T. W. Jr., Israel, D. W., Volk, R. J., Qui, J., and Sa, T. 1993. Phosphate regulation of nitrate assimilation in soybean. J. Exp. Bot. 44, 879–891.

[19] Singh, S., A.S. Dhindwal, P. Sheoran and M.S. Bhattoo. 2004. Dry matter accumulation, partitioning and translocation in late-sown wheat (Triticum aestivum) under different irrigation levels. Annals of Agri Bio Research. 2(10): 151-154.

[20] Statistical Analysis System (SAS). 2002. SAS/STAT guide for personal computers, version 9.0 editions. SAS Institute Inc., Cary, NC, USA.

[21] Thornley, J.H.M. and J. France. 2007. Mathematical models in agriculture. Quantitative methods for the plant, animal and ecological sciences. Wallingford, UK: CABI.

[22] Wardlaw, I. A. 1990. The control of carbon partitioning in plants. New Phytol. 116, 341–381.

[23] Werf, A. V. D. 1996. Growth analysis and photoassimilates partitioning. In “Photoassimilates Distribution in Plants and Crops” (E. Zamski and A. A. Schaffer, Eds.), pp. 1–20. Marcel Dekker, New York.

[24] Zobel, R. W. 1986. Rhizogenetics (root genetics) of vegetable crops. HortScience 21, 956–959.