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Response of Vetch Species for Different Drainage Methods on Vertisols in the Central Highland Areas of Ethiopia

Gezahagn Kebede[1], Fekede Feyissa[1], Getnet Assefa[2], Alemayehu Mengistu[3], Muluneh Minta[1], Tadesse Tekletsadik[1], Mamaru Tesfaye[1]

[1]Holetta Agricultural Research Center, P.O.Box 31, Holetta, Ethiopia
[2]Ethiopian Institute of Agricultural Research, P. O. Box. 2003, Addis Ababa, Ethiopia
[3]Forage and Rangeland Scientist, Urael Branch, P.O. Box 62291, Addis Ababa, Ethiopia
gezk2007@yahoo.co.uk

Abstract: *The study was conducted to evaluate the response of vicia species to different drainage methods on vertisol in the central highland areas of Ethiopia. The experiment was conducted on a split plot design using three drainage methods (CB, RF and FB) as main plot and five vicia species (V. sativa, V. villosa, V. dasycarpa "Lana", V. dasycarpa "Namoi" and V. atropurpurea) as sub-plot treatments with three replicates. The combined analysis of variance showed that drainage methods, vicia species, and locations had significant differences (P<0.05) for mean plant height, DM yield and seed yield. The results revealed that drainage method by year, species by location, location by year and species by year by location interaction effects were significant for at least one of the measured agronomic trait. The CB and RF showed 50.9% and 9.8% increments for plant height when compared with FB, respectively. The DM yield obtained at Ginchi showed 63.3% yield increment when compared with Kuyu due to differential response of the species for temperature, soil fertility and waterlogging problem. The highest DM yield (6.46 t/ha) was recorded for CB followed by RF (4.75 t/ha) and FB (2.89 t/ha). The CB and RF gave 123.5 and 64.4% DM yield increments when compared with FB, respectively. The highest DM yield was recorded for V. villosa (5.76 t/ha) followed by V. dasycarpa "Lana" (5.27 t/ha), V. atropurpurea (5.13 t/ha) and V. dasycarpa "Namoi" (3.89 t/ha) while V. sativa gave the lowest (3.47 t/ha) DM yield under different drainage methods. At Ginchi, 20.7% seed yield increment was recorded when compared with Kuyu indicating that Ginchi was relatively better location for seed production of vicia species under different drainage conditions during the experimental periods. The CB and RF drainage methods gave 151.7 and 80.6% seed yield increments over the FB drainage method, respectively. The result indicated that the highest mean seed yield was recorded for V. atropurpurea (6.08 qt/ha) followed by V. dasycarpa "Lana" (5.71 qt/ha), V. villosa (5.12 qt/ha) and V. sativa (4.83 qt/ha) while V. dasycarpa "Namoi" (3.81 qt/ha) gave the lowest seed yield under different drainage methods. Generally, the selected vicia species respond differently for measured agronomic traits under different drainage methods. Therefore, V. villosa, V. dasycarpa "Lana" and V. atropurpurea showed better performance in terms of plant height, DM yield and seed yield under different drainage methods on vertisol at Kuyu and Ginchi in the central highlands of Ethiopia.*

Keywords: *agronomic traits, drainage methods, interaction effects, vertisol, vicia species.*

1. INTRODUCTION

Vetch is an annual forage legume 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. In Ethiopia, vertisol covers 10.2% of the total soil or 12.5 million ha of which 7.6 million ha occur in highlands and is the fourth most important soil after lithosol (16.2%), cambisol (15.3%) and nitosol (11.8%) (Mesfin and Jutzi, 1989). Vertisols have crucial importance for food and feed production in Ethiopia. Bull (1988) estimates that about 11.9 million ha of vertisol areas in Ethiopia are potentially arable and can produce about 12 million tons of food grain if improved management practice would be widely adopted. This soil has clay contents between 35 and 80%, which largely determine their physical properties (Abiye and Ferew, 1993). Due to the high clay content, the water holding capacity is high, the infiltration rate low, and the internal drainage slow. Vertisols are structurally unstable, tend to slake easily under wet conditions and are easily compacted; on the other hand, the shrink–swell behavior of these soils enables aggregation and can regenerate a good structure after only a few cycles of wetting and drying (Wenke and Grant, 1994; Pillai and McGarry, 1999).

During the main growing period, waterlogging is one of the major constraints for crop production in the Ethiopian highland vertisol areas. Due to high water holding capacity of this soil, aeration becomes a limiting factor for root growth and activity, unless counterbalanced by morphological and physiological adaptation of the roots. Farmers of the vertisol areas know about the adverse effects of waterlogging on crop productivity and have developed traditional methods for overcoming it. One of this methods is planting late in the rainy season, allowing only partial use of the potential growing period.

Different drainage technologies were tested at different locations to overcome the problem of impeded drainage on vertisol, but this soil respond differently in terms of productivity for various drainage methods. According to Getachew *et al*. (2007), the traditional management of vertisol in the Ethiopian highlands varies across locations depending on the amount and duration of the rainfall, extent of drainage problem, soil fertility, slope and farm size. Appropriate technologies to better manage vertisols are a desirable intervention in the Ethiopian highland vertisol farming systems. This can be performed by improving the surface drainage. The positive effects of surface drainage on agricultural productivity of vertisols have been widely documented. Use of different drainage methods *viz*, broad-bed and furrow (BBF), ridge and furrow (RF), camber bed (CB), flat bed (FB) planting, post rainy season planting and soil burning can improve the productivity of vertisol.

It is evident that crop yields can be increased if excessive surface soil water is drained off and if appropriate cropping and soil fertility practices are used. Improved drainage had a significant effect on grain yield of crops, especially of wheat, whose yield increased by more than 100% compared to the yields from undrained plots (Abate *et al*., 1993). Fertilizer efficiency was also highest in wheat with improved drainage (Hiruy, 1986). This was further proved by the work of Ali (1992) who reported that durum wheat N use efficiency was higher on broad beds as compared to plants grown on flat beds. Despite much research has been done on the response of different food crops to various drainage methods, there is lack of information on response of vicia species to drainage methods. Therefore, the objective of this study was to evaluate the response in yield and yield components of selected vicia species to different drainage methods on vertisol in the central highland areas of Ethiopia.

2. MATERIALS AND METHODS

Description of the Test Environments

The experiment was conducted at Kuyu and Ginchi sub center during the main cropping seasons under rainfed condition. Kuyu 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 30% falls in the period from March to May (EIAR, 2005). The soil type of the area is predominantly black clay vertisol, which is characterized by an average organic matter content of 5.63%, total nitrogen 0.16%, pH 5.63, and available phosphorus 6.95 ppm (Desta, 1982). Ginchi sub center is located 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 at an altitude 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 Design and Data Collection

The experiment was conducted on black vertisol areas at Kuyu & Ginchi during the main rainy seasons of 2012 and 2013. Tractor mounted disc ploughing and harrowing was carried out in April as a common practice for general land preparation in both testing sites. Five vicia species (i.e. *V. sativa, V. dasycarpa* “Lana”, *V. dasycarpa “*Namoi”, *V. villosa and V. atropurpurea*) were selected to evaluate their performances on three different drainage methods: CB, RF and FB. The CBs (7-11 m wide) were already constructed and used in both testing sites. On the other hand, RF was made by hand immediately before planting and maintained or renewed by hand using hand hoes when required.

The experiment was conducted on a split plot design with drainage methods as main plot and vicia species as sub-plot with three replications. Seeds were sown in rows of 30 cm spacing on main plot of 4 x 12.6 m and sub plot of 4 x 2.4 m. A spacing of 1 m and 1.5 m were used between plots and blocks respectively. The materials were sown according to their recommended seeding rate: 25 kg ha^{-1} for *V. villosa, V. dasycarpa* and *V. atropurpurea*; 30 kg ha^{-1} for *V. sativa*. At sowing, 100 kg ha^{-1} DAP was uniformly applied for all treatments at both locations. Two hand weeding were performed, 30 and 60 days after emergence in both years. Agronomic parameters such as plant height, herbage yield and seed yield of vicia species were recorded for analysis. These samples were made from the interior rows. Plant height was measured using a steel tape from the ground level to the highest leaf at forage harvesting stage. For plant height determination, mean height of three randomly selected plants was recorded for each sub plot. At 50% flowering stage, plants were clipped from interior rows at 5 cm above the ground level to determine the biomass yield. Fresh biomass yield weight was recorded from each sub plot in the field and 500 g samples were taken to the laboratory. Each sub plot sample was weighed to determine fresh weight using a sensitive table balance and then oven dried for 24 hours at 105^{o}C for herbage DM yield determination. Seed samples were taken from each sub plot to determine the seed yield performance of the species. In general, appropriate agronomic managements were applied on the right time to improve the yield performance of vicia species per unit area.

Statistical Analysis

The data were subjected to analysis of variance using the GLM procedure of SAS statistical software package. Data were combined over years and locations and total variability for each measured trait was quantified using pooled analysis of variance over years and locations based on the following model: $T_{ijklm} = \mu + Y_i + L_j + R(YL)_{kij} + D_l + YD_{il} + LD_{jl} + YLD_{ijl} + R(YLD)_{kijl} + S_m + YS_{im} + LS_{jm} + YLS_{ijm} + DS_{lm} + YDS_{ilm} + LDS_{jlm} + YLDS_{ijlm} + e_{ijklm}$ where T_{ijkl} is total observation, μ= grand mean, Y_i = effect of the *i*th year, L_j is effect of jth location, $R(YL)_{kij}$ is effect of *k*th replication within *i*th year and *j*th location, D_l is effect of *l*th drainage method, S_m is effect of the *m*th species, *YD, LD, YLD, YS, LS, YLS, DS, YDS, LDS* and *YLDS* are the interactions and $R(YLD)_{kijl}$ and e_{ijklm} are the variations due to random error for main and sub-plots, respectively. Significance of the year and location effects were tested against the R(YL) mean square as the error term and the *D, YD, LD* and *YLD* effects tested against the R(YLD) mean square as an error term. All other effects were tested against the residual. Means for the main effects were separated using the means statement with the LSD at 5% significance level. When the interaction effects were significant, the LSMEANS statement using the PDIFF of the GLM procedure was used to determine the significance of simple effects.

3. Results and Discussion

Combined Analysis of Variance

The combined analysis of variance indicated that drainage methods, vicia species, and locations had significant differences for mean plant height, DM yield and seed yield performance (Table 1). However, year showed differences ($P<0.01$) for only DM yield. When genotypes performance is tested at several environments, the rankings usually differ since differences in the environment may produce different effect on specific genotypes (Caccarelli, 1997; Gemechu, 2012). Genotype by environment interaction reflects differences in adaptation and can be enhanced by selecting for specific adaptation or minimized by selecting for broad adaptation (Adjei *et al*., 2010). Therefore, multi-location evaluation of genotypes provides useful information for this broader or specific recommendation (Crossa, 1990).

Table 1. *Combined analysis of variance for quantitative traits of vicia species under different drainage methods*

Sources of variation	Plant height (cm)	DM yield (t/ha)	Seed yield (qt/ha)
Drainage (DR)	*	**	**
Species (SP)	***	**	**
Location (L)	*	**	*
Year (Y)	NS	**	NS
DR*Y	NS	*	*
SP*L	*	*	*
L*Y	***	**	NS
SP*Y*L	NS	NS	*

*= P<0.05, **= P<0.01, ***= P<0.001, NS= non-significant, All other possible interaction effects were not significant.

Main and Interaction Effects on Plant Height

The year and location effects on plant height of vicia species grown under different drainage methods are indicated in Table 2. The results indicated that mean plant height of vicia species was not different (P>0.05) between the two experimental years. However, higher mean plant height was obtained in 2012 cropping season. Plant height was not significantly (P>0.05) affected by years indicating consistency of genotypes performance in both years due to similar growing conditions (rainfall, humidity, temperature etc.) between the experimental years. On the other hand, plant height was different (P<0.05) between the two experimental locations. The highest mean plant (115.6 cm) was recorded at Ginchi while at Kuyu the mean plant height was 80.0 cm. Effect of drainage methods on mean plant height of five vicia species and mean plant height of each species combined under different drainage methods are presented in Table 3. The results showed that plant height of vicia species significantly affected (P<0.05) by drainage methods. The highest mean plant height was recorded in CB followed by RF and FB. The CB and RF showed 50.9% and 9.8% increments for plant height when both were compared with FB. Similarly, CB gave 37.4% increment for plant height over the RF drainage method. The species mean plant height combined under different drainage methods also varied significantly (P<0.05). The results revealed that the highest mean plant height was recorded for *Vicia villosa* (120.8 cm) followed by *V. dasycarpa* "Lana" (107.3 cm), *V. atropurpurea* (105.2 cm) and *V. dasycarpa* "Namoi" (99.2 cm) while the lowest (56.5 cm) recorded for *V. sativa* indicating differential response of the species for waterlogging problem on vertisol. Plant height is one of the important agronomic traits affected by variation in genetic, soil fertility, climate and agronomic management (Kebede *et al*., 2016).

Table 2. *Plant height (cm) of vicia species under different drainage methods over years and locations*

SN	Year	Plant height (cm)	Location	Plant height (cm)
1	2012	98.5	Kuyu	80.0^{b}
2	2013	97.0	Ginchi	115.6^{a}
	P-value	**0.7919**	**P-value**	**0.0192**

Different superscript letters in the same column represents significant differences (P<0.05).

Table 3. *Effect of drainage methods on plant height (cm) of vicia species and response of the species for plant height under different drainage methods*

SN	Drainage method	Plant height (cm)	SN	Species	Plant height (cm)
1	Camber bed	122.7^{a}	1	*Vicia sativa*	56.5^{d}
2	Ridges and furrows	89.3^{b}	2	*V. villosa*	120.8^{a}
3	Flat bed	81.3^{c}	3	*V. dasycarpa* "Lana"	107.3^{b}
	P-value	**0.0375**	4	*V. dasycarpa* "Namoi"	99.2^{c}
			5	*V. atropurpurea*	105.2^{bc}
				P-value	**0.0001**

Different superscript letters in the same column represents significant differences (P<0.05).

The year by location interaction effects for mean plant height of vicia species is indicated in Figure 1. The results showed that the interaction effects varied significantly (P<0.05) for plant height. The highest and significant (P<0.05) mean plant height was recorded at Ginchi followed by Kuyu in 2013 cropping season. On the other hand, higher plant height was recorded at Kuyu followed by Ginchi in 2012. This crossover indicated a change in the plant height ranking order at both locations in the two experimental years.

Species by location interaction effects for mean plant height is given in Figure 2. The results indicated that species by location interaction effects varied significantly (P<0.05) for mean plant height. All vicia species gave higher mean plant height at Ginchi when compared with Kuyu, but no rank order changes. This interaction effect was found to be significant (P<0.05) for all vicia species except for *V. sativa*. Genotype by environment interaction refers to the differential responses of different genotypes across a range of environments (Kang, 2004). In breeding programs, genotype by environment interaction cause many difficulties, whereas the environmental factors such as temperature and waterlogging stress affect the performance of genotypes. Consequently, multi-environment trials are widely used by plant breeders to evaluate the relative performance of genotypes for target environments (Delacy *et al*., 1996). If genotypes perform consistently across stressed and favorable environments, breeders may be able to efficiently evaluate genotypes in the favorable environment for both the favorable and stressed environments (Gemechu *et al*., 2001).

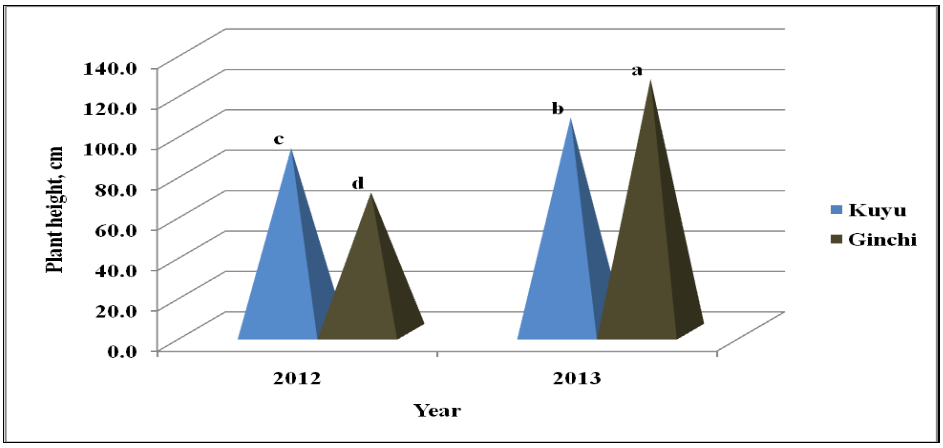

Figure 1. *Year by location interaction for plant height of vicia species*

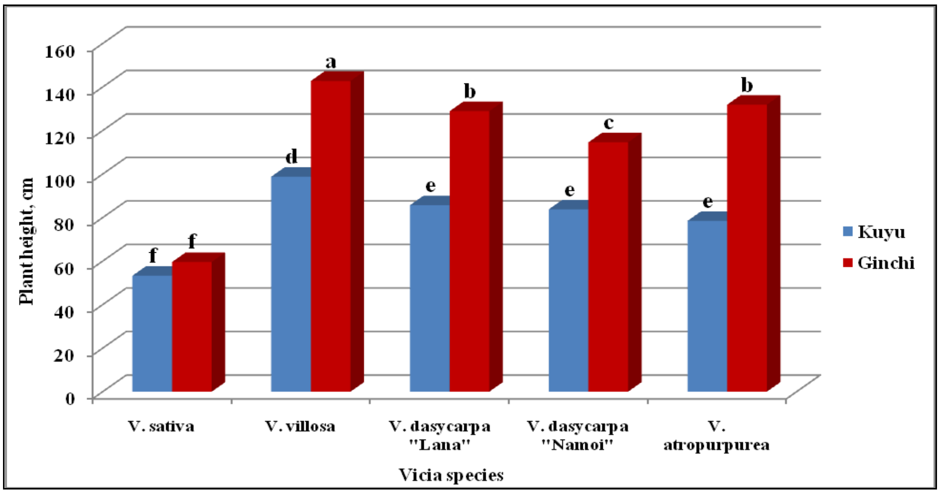

Figure 2. *Species by location interaction for plant height of vicia species*

Main and Interaction Effects on Herbage Yield

The DM yield response of vicia species under different drainage methods in both years and locations is presented in Table 4. DM yield of vicia species under different drainage methods was different (P<0.05) between the two years. Accordingly, the highest DM yield mean (5.22 t/ha) was recorded in 2012 cropping season. Also, DM yield was significantly affected (P<0.05) by locations. Ginchi had higher DM yield (5.83 t/ha, mean) when compared with Kuyu. The DM yield obtained at Ginchi showed 63.3% yield increment when compared with Kuyu due to differential response of the species for temperature, soil fertility and waterlogging problem. Effect of drainage methods on mean DM yield of five vicia species and mean DM yield of each species combined under different drainage methods are presented in Table 5. DM yield was significantly affected (P<0.05) by different drainage methods. The highest DM yield (6.46 t/ha) was recorded for CB followed by RF (4.75 t/ha) and FB (2.89 t/ha). The CB and RF were 123.5 and 64.4% DM yield higher when compared with FB respectively. Moreover, CB gave 36.0% DM yield increment when compared with RF. The tested vicia species respond differently (P<0.05) for mean DM yield combined under different drainage methods. The highest DM yield was recorded for *Vicia villosa* (5.76 t/ha) followed by *V. dasycarpa* "Lana" (5.27 t/ha), *V. atropurpurea* (5.13 t/ha) and *V. dasycarpa* "Namoi" (3.89 t/ha) while *V. sativa* gave the lowest (3.47 t/ha) DM yield. Getnet and Ledin (2001) 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. Waterlogging due to the impervious nature of the soil and poor drainage are predominant problems to increased production on these soils (Getachew *et al*., 1993; Efrem *et al*., 1996). The severity of the constraint varies from area to area depending on the clay content of the soil, rainfall and soil temperature which also depends on the moisture content of the soil. However, Getachew *et al*. (1988, 1993), indicated that crop yields can be improved through specific land preparation techniques. Several authors reported increase yields of some crops grown on vertisols due to the use of the BBF as compared to the FB (Abiye *et al*., 1995; Haque *et al*., 1996; Muhamed- Saleem and Abiye, 1996). The same authors suggest that the improvement in surface drainage and yield was spectacular during the excessive rainy years. According to Gemechu *et al*. (2001), the trials under FB conditions suffered 20-50% yield reduction as compared to BBF. The same authors indicated that with the improvement of drainage conditions, the crop yield increases in 59.2% and 64.9% for local and improved cultivars.

Table 4. *DM yield (t/ha) response of vicia species for different drainage methods over years and locations*

SN	Year	DM yield (t/ha)	Location	DM yield (t/ha)
1	2012	5.22[a]	Kuyu	3.57[b]
2	2013	4.18[b]	Ginchi	5.83[a]
	P-value	**0.0151**	**P-value**	**0.0033**

Different superscript letters in the same column represents significant differences ($P<0.05$)

The year by location interaction affects ($P<0.05$) for DM yield of vicia species as indicated in Figure 3. The two locations showed non-significant difference ($P>0.05$) for DM yield in 2013 but varied significantly ($P<0.05$) in 2012. Accordingly, the highest DM yield was recorded at Ginchi in 2013 while Kuyu gave the highest DM yield in 2012 indicating a change in DM yield ranking order at both locations in the two experimental years.

Drainage by year interaction effects for DM yield was found to be significant ($P<0.05$) as indicated in Figure 4. DM yield obtained from CB and RF were affected by years but no differences were observed on FB between the two years. CB and RF gave the highest and significant DM yield in 2012, although FB gave the highest DM yield in 2013. Species by location interaction effects for DM yield different ($P<0.05$) as indicated in Figure 5. The highest DM yield was recorded at Ginchi for all vicia species except *Vicia dasycarpa* “Namoi” which gave better yield at Kuyu. Species response for DM yield varied significantly between the two locations except *Vicia dasycarpa* “Namoi”. In general, *Vicia villosa*, *V. dasycarpa* “Lana” and *V. atropurpurea* gave higher DM yield under different drainage methods at Ginchi. Similarly, *Vicia villosa*, *V. dasycarpa* “Lana” *V. dasycarpa* “Namoi” gave higher DM yield at Kuyu indicating that species respond differently under different environmental conditions.

Table 5. *Effect of drainage methods on DM yield (t/ha) and response of vicia species for DM yield under different drainage methods*

SN	Drainage method	DM yield (t/ha)	SN	Species	DM yield (cm)
1	Camber bed	6.46[a]	1	*Vicia sativa*	3.47[b]
2	Ridges and furrows	4.75[b]	2	*V. villosa*	5.76[a]
3	Flat bed	2.89[c]	3	*V. dasycarpa* “Lana”	5.27[a]
	P-value	**0.0039**	4	*V. dasycarpa* “Namoi”	3.89[b]
			5	*V. atropurpurea*	5.13[a]
				P-value	**0.0069**

Different superscript letters in the same column represents significant differences ($P<0.05$)

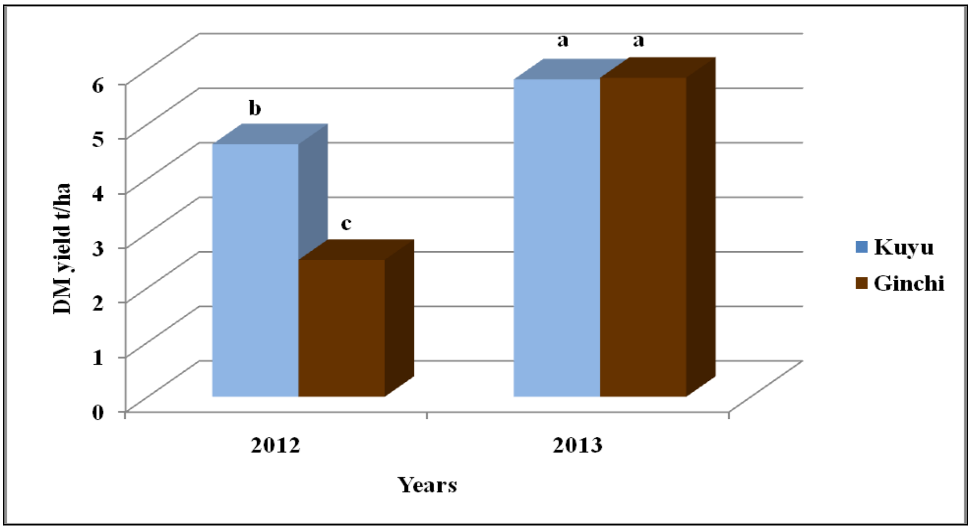

Figure 3. *Year by location interaction for DM yield of vicia species*

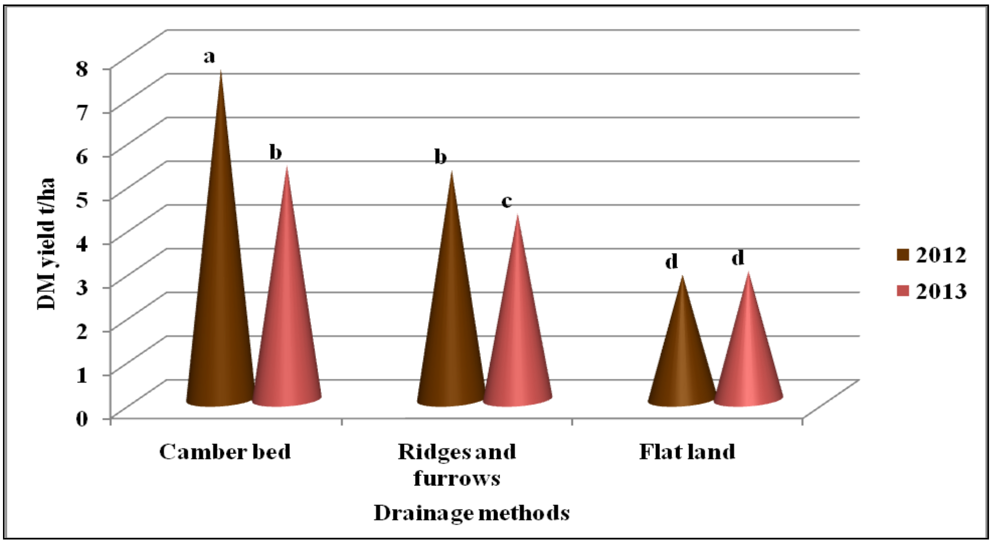

Figure 4. *Drainage by year interaction for DM yield of vicia species*

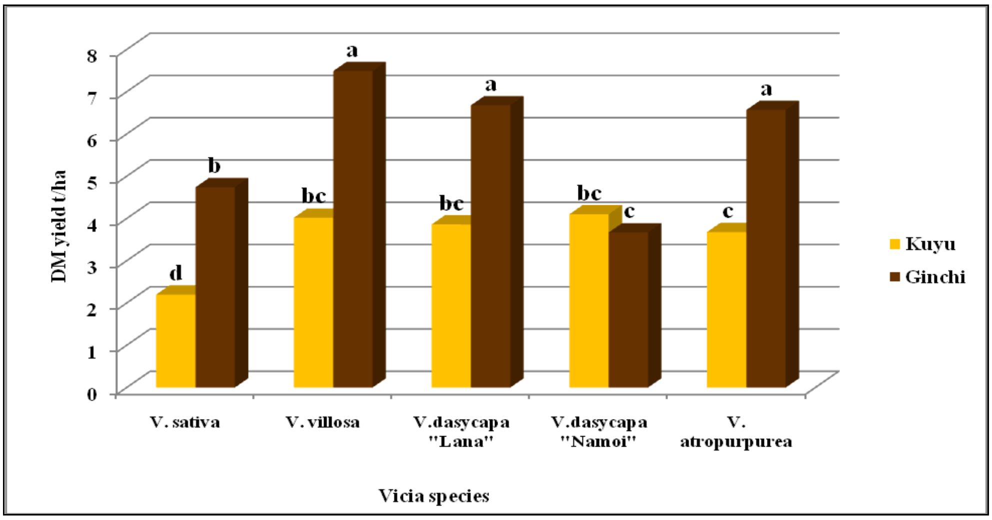

Figure 5. *Species by location interaction for DM yield of vicia species*

Main and Interaction Effects on Seed Yield

The seed yield performance of vicia species under different drainage methods in both years and locations is indicated in Table 6. The results showed that seed yield was not significantly affected (P>0.05) by experimental years, however, the variation was significant for locations. The highest seed yield was recorded in 2012 (5.21 qt/ha) cropping season and at Ginchi (5.59 qt/ha) location when compared with other experimental year and location. At Ginchi, 20.7% seed yield increment was recorded when compared with Kuyu indicating that Ginchi was relatively better location for seed production of vicia species during the experimental periods. Effect of drainage methods on seed yield of vicia species and their response for seed yield under different drainage methods affected significantly (P<0.05) as indicated in Table 7. The highest seed yield was recorded for CB (7.25 qt/ha) followed by RF (5.20 qt/ha) while FB (2.88 qt/ha) gave the lowest seed yield. The CB and RF drainage methods gave 151.7 and 80.6% seed yield increments over the FB, respectively. Similarly, the CB drainage method gave 39.4% seed yield increments when compared with RF drainage method. This indicates that the use of appropriate surface drainage methods contributes to seed yield increments of vicia species under waterlogged conditions.

The seed yield performance of vicia species also varied significantly (P<0.05) under different drainage methods. The result indicated that the highest mean seed yield was recorded for *V. atropurpurea* (6.08 qt/ha) followed by *V. dasycarpa* “Lana” (5.71 qt/ha), *V. villosa* (5.12 qt/ha) and *V. sativa* (4.83 qt/ha) while *V. dasycarpa* “Namoi” (3.81 qt/ha) gave the lowest seed yield. Experimental findings also showed that planting chickpea, lentil and faba bean on BBF resulted in grain yield increments compared to un-drained FB conditions (Getachew and Amare, 2004). Mean grain yields of chick pea on BBF and RF increased by 59 and 46 % (Getachew *et al*., 2007) and its grain and straw yield increments of 106 and 78% occurred under BBF compared to FB (Abate *et al*., 1993). According to Gemechu and Musa (2002) findings, reductions under FB were 19% for number of pods/plant, 4% and 1% for number of seeds/pod and 1000 seed weight, respectively, and 18% for grain yield. This may indicate that a significant portion of yield reduction under flat bed conditions was attributed to the sensitivity of number of pods/plant to waterlogging (Gemechu and Musa, 2002). This is in agreement with the general trend that genotypes normally better express their genetic potential under favorable environments as compared to the stressed ones (Singh, 1990; Simmonds, 1991; Banziger and Edmeades, 1997). Our results showed that, on average, drainage increased seed yield by 45% compared with the FB system.

Table 6. *Seed yield (qt/ha) of vicia species under different drainage methods over years and locations*

SN	Year	Seed yield (qt/ha)	Location	Seed yield (qt/ha)
1	2012	5.21	Kuyu	4.63^{b}
2	2013	5.00	Ginchi	5.59^{a}
	P-value	**0.2260**	**P-value**	**0.0156**

Different superscript letters in the same column represents significant differences ($P<0.05$)

Table 7. *Effect of drainage methods on seed yield (qt/ha) and response of vicia species for seed yield under different drainage methods*

SN	Drainage method	Seed yield (qt/ha)	SN	Species	Seed yield (qt/ha)
1	Camber bed	7.25^{a}	1	*Vicia sativa*	4.83^{c}
2	Ridges and furrows	5.20^{b}	2	*V. villosa*	5.12^{bc}
3	Flat bed	2.88^{c}	3	*V. dasycarpa* "Lana"	5.71^{ab}
	P-value	**0.0023**	4	*V. dasycarpa* "Namoi"	3.81^{d}
			5	*V. atropurpurea*	6.08^{a}
				P-value	**0.0045**

Different superscript letters in the same column represents significant differences ($P<0.05$);

1qt = 100 kg

Drainage by year interaction effects for seed yield of vicia species varied significantly ($P<0.05$) as indicated in Figure 6. Significant interactions were observed between the two experimental years under CB drainage method while no differences were observed between the two years under RF and FB drainage methods. The highest seed yield was recorded under CB drainage method in 2012 when compared with 2013, however, the remaining two drainage methods gave the highest seed yield in 2013 when compared with 2012. Species by location interaction effects for seed yield of vicia species varied significantly ($P<0.05$) as indicated in Figure 7.

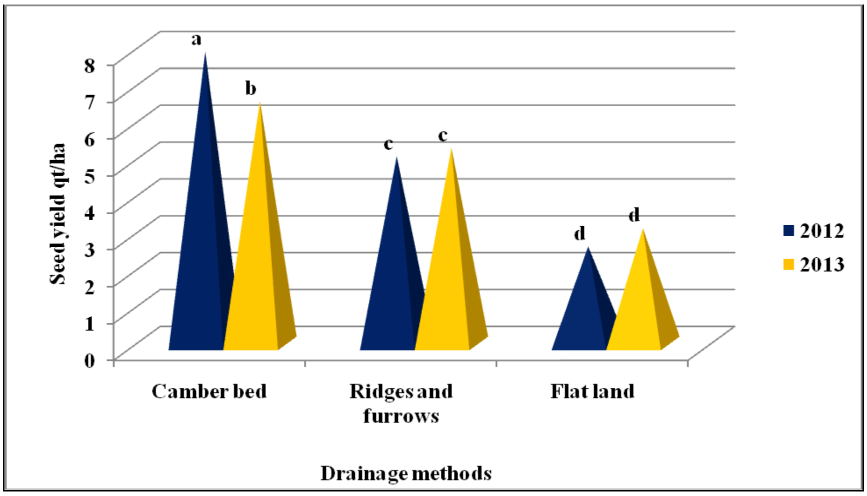

Figure 6. *Drainage by year interaction for seed yield of vicia species*

All species showed significant variation ($P<0.05$) between the two locations except for *V. atropurpurea*. The highest seed yield recorded at Ginchi was for *V. atropurpurea* followed by *V. villosa* and *V. dasycarpa* "Lana", however, at Kuyu the highest seed yield was obtained from *V. atropurpurea* followed by *V. dasycarpa* "Lana" and *V. dasycarpa* "Namoi". According to Getachew and Woldeyesus (2012) findings, the highly significant drainage method by variety interaction for seed yield could be due to the greater yield of improved varieties under improved drainage conditions compared with FB conditions. These results confirm the often claimed better performance of modern varieties under optimal management conditions but not under stress conditions (Sinebo, 2005).

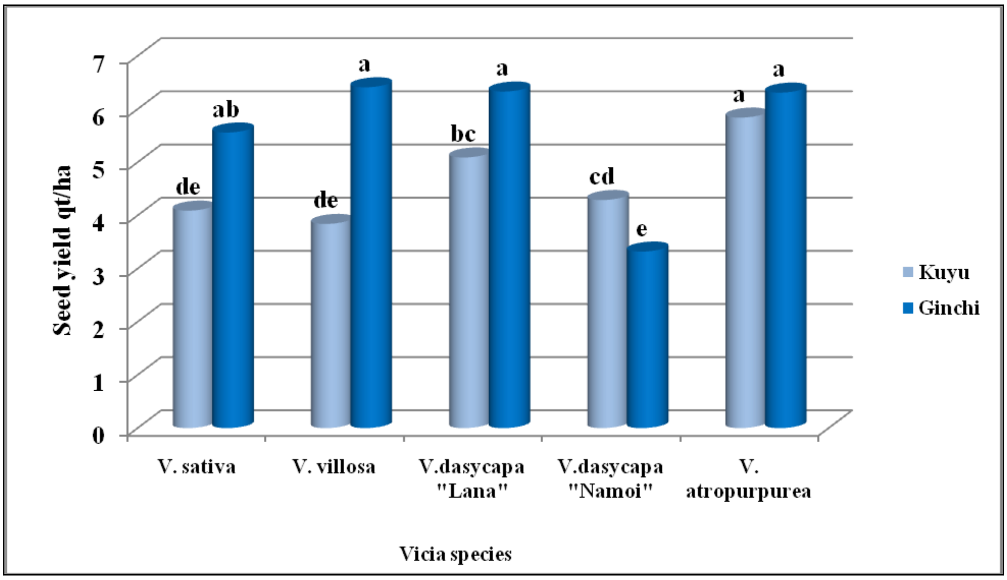

Figure 7. *Species by location interaction for seed yield of vicia species*

4. Conclusion

The combined analysis of variance showed that drainage methods, vicia species, and locations had significant differences for mean plant height, DM yield and seed yield. The results revealed that drainage method by year, species by location, location by year and species by year by location interaction effects were significant for at least one of the measured agronomic trait. The CB and RF showed increments for plant height, DM yield and seed yield when compared with FB. Similarly, CB showed increment for plant height, DM yield and seed yield over the RF drainage method. The highest DM yield was recorded for *V. villosa* followed by *V. dasycarpa* "Lana", *V. atropurpurea* and *V. dasycarpa* "Namoi" while *V. sativa* gave the lowest DM yield under different drainage methods. Similarly, the highest seed yield was recorded for *V. atropurpurea* followed by *V. dasycarpa* "Lana", *V. villosa* and *V. sativa* while *V. dasycarpa* "Namoi" gave the lowest seed yield under different drainage methods. Higher plant height, better DM and seed yields were obtained at Ginchi when compared with Kuyu and in 2012 when compared with in 2013 cropping season indicating that locations and years affects the measured agronomic traits of vicia species under different drainage methods. Generally, the species respond differently for measured agronomic traits under different drainage methods. Therefore, *V. villosa, V. dasycarpa* "Lana" and *V. atropurpurea* showed better performance in terms of plant height, DM yield and seed yield under different drainage methods on vertisol at Kuyu and Ginchi in the central highlands of Ethiopia.

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