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Research Paper

Determination of appropriate seeding rate for oats/vetch mixtures grown under different drainage conditions of vertisols in the central highlands of Ethiopia

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Abstract. The study was conducted to determine the optimum seeding rate for oats/vetch mixtures on vertisols and to evaluate the effect of waterlogging problem on productivity of oats/vetch mixtures during the main cropping seasons of 2012 and 2013 in the central highlands of Ethiopia. The experiment was conducted on a split-split plot design with three drainage methods (camber beds (CB), ridges and furrows (RF) and flat beds (FB)) as a main plot, four oats/vetch species mixtures (CI-8251/*Vicia dasycarpa*, CI-8251/*Vicia villosa*, CI-8251/*Vicia sativa* and CI-8251/*Vicia atropurpurea*) as a sub plot and four oats/vetch mixtures seeding rates (75/25, 105/35, 135/45 and 165/55kg/ha for oats/vetch, respectively) as a sub-sub plot treatments replicated three times. The result depicted that drainage methods had a significant effect ($P < 0.05$) on plant height and DM yield of oats/vetch mixtures. The DM yield produced from CB and RF were higher by 29.0 and 8.0%, respectively, over FB conditions, implying improved drainage methods have a tremendous contribution for oats/vetch mixtures to express their genetic potential due to reduced waterlogging stress when compared to FB conditions. On the other hand, CB showed 13.4 and 29.0% increments in plant height and DM yield respectively, compared to RF drainage conditions. The highest plant height and DM yield of oats/vetch mixtures were recorded from CB followed by RF and FB drainage conditions. On the other hand, relatively better mixtures DM yield was obtained from CI-8251/*Vicia villosa* followed by CI-8251/*Vicia sativa* and CI-8251/*Vicia dasycarpa* while CI-8251/*Vicia atropurpurea* produced the lowest mixtures DM yield under different drainage conditions. Generally, mixtures of CI-8251/*Vicia villosa* produced better plant height and DM yield under different drainage conditions on vertisols implying that these mixtures had good compatibility and less sensitivity of *Vicia villosa* for waterlogging problems. The highest DM yield was obtained from seeding rate of 105/35 kg/ha followed by 135/45 kg/ha and 165/55 kg/ha while the lowest DM yield was recorded from the control (75/25 kg/ha) seeding rate. The DM yield of oats/vetch mixtures sown with seeding rates of 105/35, 135/45 and 165/55kg/ha had yield advantages of 7.6, 5.1 and 4.3%, respectively, when compared to the control (75/25 kg/ha) seeding rate. Therefore, seeding rate of 105/35 kg/ha is recommended for oats/vetch mixtures grown on vertisol conditions in the central highlands of Ethiopia.

Keywords: Drainage methods, dry matter yield, oats/vetch mixtures, seeding rate, vertisol.

INTRODUCTION

In the Ethiopian highlands, the farming system is characterized by crop-livestock mixed farming systems. Population pressure, unreliable rainfall, poor soil fertility and frost are some of the major challenges of the areas and these significantly contributed to feed shortage problems both in quantity and quality. Vertisols are typical soil types of the country with significant agricultural importance. Vertisols account for 12.7 million hectares in Ethiopia of which 7.6 million hectares are in the Ethiopian highlands (Tekalign *et al*., 1993). Despite this soil is very fertile, its productivity is constrained by unique soil physical properties. 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. Deckers *et al*. (2001) stated that vertisols are among the most vulnerable soils to erosion, depending on how they are managed and on their topsoil structure and texture. Vertisols are generally hard when dry and sticky when wet and therefore present serious limitations to their use. Cracks are a unique feature in soils with strong shrink–swell potential and are used as one of the criteria in defining vertisols and vertic intergrades in soil taxonomy (Soil survey staff, 1992). The extent of cracking depends on the nature and amount of clay, soil depth, subsoil materials and the length of drying period (Bandyopadhyay *et al*., 2003). Upon wetting, some clay particles disperse and migrate downward with percolating water and are deposited at the bottom of cracks, or in the pore spaces (Waller and Wallender, 1993). The concentration of clay in subsurface horizons may be beneficial or detrimental, depending on the degree of accumulation. To some extent, higher concentration of clay in subsoil layers leads to greater retention of soil moisture as well as nutrients. High accumulation of clay beyond a certain limit leads to the formation of clay pan restricting root penetration and movement of air and water.

Traditional farming has developed a wide range of drainage practices and the use of low yielding crop varieties and late planting practices to avoid waterlogging periods (Tekalign *et al*., 1993). Research findings indicated that traditionally many vertisol crops are planted towards the end of the main rainy season and grow on residual moisture (Abate *et al*., 1988). Despite the yield advantage and concerted effort of popularization during the last decades, broad bed and furrow drainage method is not well adopted by framers. This was attributed to economic, environmental, socio-cultural, technical and policy constraints (Fassil *et al*., 2000; Pankhurst, 2000). Cultivation of oats/vetch mixtures on vertisol has a paramount importance for attainment of better quantity and quality of feeds for livestock production. But the performance of mixtures grown forages vary with the type of soil, compatibility, seeding rates of the mixtures and management practices. Muluneh (2006) reported that the yield of vetch species produced on red soil was more than double compared to the results recorded on black soil, because this soil has a problem of waterlogging in rainy season 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, blanket mixtures seeding rates recommendation (75/25 kg/ha for oats/vetches respectively) has been used for both red nitosol and black vertisols for the last so many years though both soil types vary with physical and chemical properties (Getnet and Ledin, 2001). Due to occurrence of aeration problem under waterlogged condition of vertisol, most emerged seedlings die which causes remarkable yield loss. Therefore, the objectives of this study were to determine the optimum seeding rate for oats/vetch mixtures on vertisols and to evaluate the effect of waterlogging problem on productivity of oats/vetch mixtures in the central highlands of Ethiopia.

MATERIALS AND METHODS

Descriptions of the test environments

The experiment was conducted on black vertisol at Kuyu site and Ginchi sub center of Holetta Agricultural Research Center (HARC) during the main cropping seasons of 2012 and 2013. The test locations located in the central highland areas of Ethiopia. The rainfall of the test locations is bimodal and about 70% of the precipitation falls in the period from June to September, while the remaining thirty percent falls in the period from March to May (EIAR, 2005). The farming system of the study area is mixed crop livestock production system and some of the major descriptions of the test environments are indicated in Table 1.

Experimental design and layout

The experiment was conducted on vertisol at Kuyu and Ginchi during the main rainy seasons for two years. One oats variety (CI-8251) which is recommended for vertisol so far and four well adapted vicia species (*Vicia dasycarpa*, *Vicia villosa*, *Vicia sativa* and *Vicia atropurpurea*) were used for execution of this experiment. Four oats/vetch mixtures seeding rates (75/25, 105/35, 135/45 and 165/55 kg/ha) including blanket recommendation were used to compare and select the appropriate oats/vetch mixtures seeding rate for vertisol conditions. The experiment was conducted on a split-split plot design with drainage methods as a main plot, oats/vetch species mixtures as a sub plot and oats/vetch mixtures seeding rates as a sub-sub plot treatments repli-

Table 1. Descriptions of the test environments for geographical position and physico- chemical properties of the soils.

SN	Parameter	Kuyu	Ginchi
1	Latitude	9° 00'N	9° 02'N
2	Longitude	38° 30'E	38° 12'E
3	Altitude (masl)	2400	2200
4	Distance from Addis Ababa (km)	29	75
5	Annual rainfall (mm)	1044	1095
6	Daily minimum temperature (°C)	6.2	8.4
7	Daily maximum temperature (°C)	21.2	24.6
8	Soil type	Vertisol	Vertisol
9	Textural class	Clay	Clay
10	pH (1:1 H_2o)	5.63	6.50
11	Total organic matter (%)	5.63	1.30
12	Total nitrogen (%)	0.16	0.13
13	Available phosphorous (ppm)	6.95	16.50

cated three times. The experimental treatments were subjected to camber beds (CB), ridges and furrows (RF) and flat beds (FB) conditions. The constructed camber beds, 7 to 11 m wide, were used in both testing sites. On the other hand, ridges and furrows were made by hand immediately before planting and maintained or renewed by hand using hand hoes when required. The treatments were sown in rows of 30 cm spacing between rows. The blocks were separated by a 2 m wide open space whereas the plots within a block were separated by a 1 m wide space. DAP fertilizer at a rate of 100 kg/ha was uniformly applied for all treatments at sowing. Land preparation, weeding and all other management factors were the same for all experimental units at each location and year. The first hand weeding was made thirty days after crop emergence and the second weeding was done thirty days after the first weeding in both years and locations. Moreover, appropriate agronomic managements were applied on the right time to improve the yield per unit area.

Agronomic data collection and measurements

Samplings for plant height and dry matter (DM) yield of oats/vetch mixtures were made from the interior rows. Plant height was determined by measuring the lengths of sample plants from the ground level to the top of the plants at milk stage of oats which is the recommended stage for harvesting of oats/vetch mixtures planting. Six plants (3 oats and 3 vetch species) were randomly selected from each plot and their heights were taken at milk stage of oats. For DM yield determination, the plants were harvested close to the ground level by hand using sickles at recommended forage harvesting stage of the mixture plants. Weight of the total fresh biomass yield was recorded from each plot in the field and the estimated 500 g sample was taken from each plot to the laboratory. The sample taken from each plot was weighed to know the sample fresh weight using sensitive table balance and oven dried for 24 h at a temperature of 105°C for herbage DM yield determination.

Data analysis

The data obtained from two consecutive years of study were statistically analyzed following the split–split plot design procedures (Gomez and Gomez, 1984). The collected data were subjected to analysis of variance (ANOVA) using the general linear model (GLM) procedure of SAS statistical software packages (SAS, 2002). Data were combined over years and locations and total variability for both measured traits were quantified using pooled analysis of variance over years and locations. Significant treatment means were separated using the least significant difference (LSD) test. The significant differences among the main effects were compared with the critical difference at 5% level of probability. Means for the main effects were separated using the MEANS statement with the LSD. However, 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.

RESULTS AND DISCUSSION

Combined analysis of variance

The combined analysis of variance (ANOVA) for main effects indicated that drainage methods and species mixtures had significant difference for mean plant height and DM yield of oats/vetch mixtures (Table 2). Moreover, seeding rate and location main effects varied significantly

Table 2. Combined analysis of variance for measured traits of oats/vetch mixtures planted with various seeding rates under different drainage methods on vertisol.

Sources of variations	Plant height	DM yield
Drainage methods (DR)	***	***
Species mixtures (SM)	***	***
Seeding rate (SR)	NS	***
Location (L)	NS	*
Year (Y)	NS	NS
SM*L	**	*
SR*L	NS	*
SM*Y	***	*
Y*L	NS	*
DR*L*Y	***	***
SM*Y*L	***	*
DR*SM*Y	**	NS

* = $P < 0.05$, ** = $P < 0.01$, *** = $P<0.001$, NS = non-significant; and all other possible interaction effects were not significant.

Table 3. Agronomic response of oats/vetch mixtures sown with various seeding rates under different drainage conditions over years and locations.

Year	Plant height (cm)	DM yield (t/ha)	Location	Plant height (cm)	DM yield (t/ha)
2012	126.1	9.13	Kuyu	119.8	7.60[b]
2013	123.7	9.14	Ginchi	130.0	10.67[a]
Mean	124.9	9.14	Mean	124.9	9.14
CV	12.1	20.3	CV	12.1	20.3
P-value	0.6489	0.9812	P-value	0.1584	0.0292

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

for DM yield. On the other hand, the interaction effects of species mixture by location, species mixture by year, drainage methods by year by location and species mixture by year by location showed significant difference for plant height and DM yield. Moreover, the interaction effects of seeding rate by location and year by location showed significant difference for DM yield while drainage methods by species mixture by year varied significantly for plant height. Genotype by environment interaction is the result of changes in cultivar's relative performance across environments due to differential responses of the genotypes to various edaphic, climatic and biotic factors (Dixon and Nukenine, 1997). Yield of any crop depends on genotype, environment and management practices and their interaction with each other (Messina *et al*., 2009). Under the same management conditions, variation in yield is principally explained by the effects of genotype and environment (Dingkuhn *et al*., 2006). 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). Interaction between these two explanatory variables gives insight for identifying genotype suitable for specific and/or broad environments. Therefore, multi-location evaluation of genotypes provides useful information for this broader or specific recommendation (Crossa, 1990).

Main effects of year and location on oats/vetch mixtures performance

The year and location effects on oats/vetch mixtures planted under different drainage methods are indicated in Table 3. The result depicted that there is no significant differences ($P > 0.05$) between the two experimental years for mean plant height and DM yield of oats/vetch mixtures. Relatively better mean plant height was recorded in the year 2012 while slightly higher DM yield was recorded in the year 2013. No significant difference between the two experimental years indicating that the two experimental years had more or less similar in distribution and amount of rainfall. On the other hand, DM yield was significantly affected ($P < 0.05$) by location effects while plant height did not vary ($P > 0.05$) between the two locations. The result indicated that the highest mean plant height (130.0 cm) and DM yield (10.67 t/ha) were recorded at Ginchi when compared to Kuyu site.

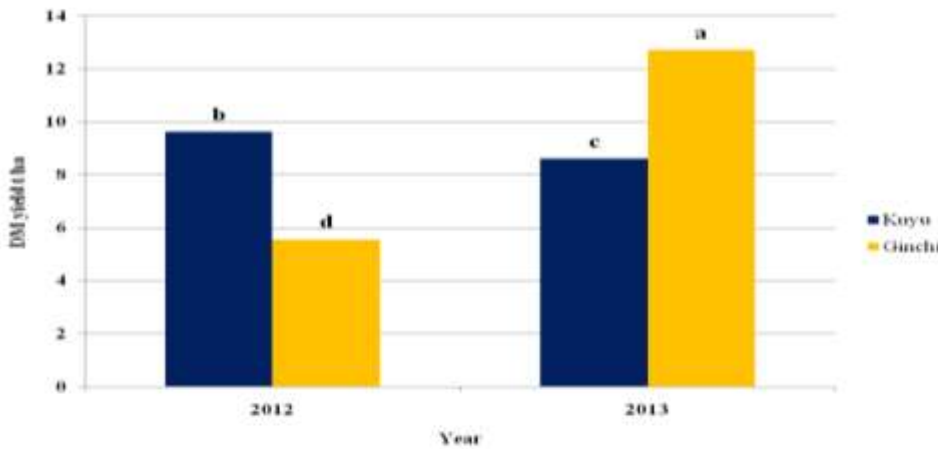

Figure 1. Year by location interactions for DM yield of oats/vetch mixtures.

Ginchi site had 8.5% plant height and 40.4% DM yield advantages over Kuyu site indicating that the site had relatively less waterlogging problem and/or received less amount and better distribution of rainfall when compared to Kuyu site during the experimental years. Waterlogging is a stress due to excess water that corresponds to the full saturation of the soil pores with water and with a very thin or without a layer of water above the soil surface (Striker, 2012). Waterlogging is a major abiotic stress adversely affecting crop productivity worldwide (Shimono *et al*., 2012). The magnitude of adverse effect from waterlogging in a species varies depending on the phase of exposure, nature of the genotype and duration of the stress. Waterlogging leads to several effects on plants including restricted root growth (Thomson *et al*., 1990), reductions in stomatal conductance and assimilation rate (Oosterhuis *et al*., 1990) and reduced nutrient uptake leading to low productivity (Robertson *et al*., 2009).

Year by location interaction effects for DM yield of oats/vetch mixtures

Year by location interaction effects for DM yield of oats/vetch mixtures sown with various seeding rates under different drainage conditions on vertisol vary significantly ($P < 0.05$) as indicated in Figure 1. The result revealed that significantly ($P < 0.05$) the highest and lowest DM yield were recorded at Ginchi in 2013 and 2012 cropping season, respectively. At Kuyu site, the highest DM yield of oats/vetch mixtures sown with various seeding rates under different drainage condition was obtained in 2012 when compared to 2013 cropping season. The interaction effect was crossover this indicates change in ranking order of DM yield performance between the two locations when compared to the two experimental years this might be due to inconsistency in amount and distribution of rainfall between the two locations and years. In fact crop performance is strongly influenced by weather conditions. So, vulnerability of cultivars to environmental variation can be also viewed as a barrier to imposing yield potential. The yielding ability of genotype is the result of its interaction with the environment and environmental factors such as soil characteristics, moisture and temperature over years and locations have an impact on yield performance (Gezahagn *et al*., 2017a). Yield is a complex quantitative character and is greatly influenced by environmental fluctuations; hence, the selection for superior genotypes based on yield *per se* at a single location in a year may not be very effective (Shrestha *et al*., 2012).

Main effects of drainage methods on oats/vetch mixtures performance

Effect of drainage methods on mean plant height and DM yield of oats/vetch mixtures are indicated in Table 4. The result revealed that drainage methods had significant effect ($P < 0.05$) on plant height and DM yield of oats/vetch mixtures. Plant height of oats/vetch mixtures ranged from 118.4 to 136.2 cm with a mean of 124.9 cm under different drainage methods. Similarly, DM yield of oats/vetch mixtures grown on different drainage methods ranged from 7.89 to 10.99 t/ha with a mean of 9.14 t/ha. Plants harvested from camber beds (CB) and ridges and furrows (RF) had plant height advantages of 15.0 and 1.4%, respectively, over flat bed (FB) conditions. Similarly, DM yield produced from CB and RF were higher by 29.0 and 8.0%, respectively, over FB conditions, implying improved drainage methods have a tremendous contribution for genotypes (oats/vetch) to express their genetic potential due to reduced waterlogging stress when compared to FB conditions. On the other hand, CB showed 13.4 and 29.0% increments in plant height and DM yield respectively, when compared to RF drainage conditions. The highest plant

Table 4. Combined effect of different drainage methods on agronomic performance of oats/vetch mixtures sown with different seeding rates over years and locations.

Drainage methods	Plant height (cm)	DM yield (t/ha)
Camber bed	136.2[a]	10.99[a]
Ridges and furrows	120.1[b]	8.52[b]
Flat bed	118.4[b]	7.89[c]
Mean	124.9	9.14
CV	12.1	20.3
P-value	0.0001	0.0001

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

Table 5. Combined agronomic response of oats/vetch mixtures sown with various seeding rates under different drainage methods over years and locations

SN	Species	Plant height (cm)	DM yield (t/ha)
1	CI-8251/*V. dasycarpa*	128.9[ab]	9.00[b]
2	CI-8251/*V. villosa*	131.3[a]	9.60[a]
3	CI-8251/*V. sativa*	113.0[c]	9.02[b]
4	CI-8251/*V. atropurpurea*	126.2[b]	8.92[b]
	Mean	124.9	9.14
	CV	12.1	20.3
	P-value	0.0001	0.0073

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

height and DM yield of oats/vetch mixtures were recorded from CB followed by RF and FB drainage conditions. Other research findings also indicated that improved drainage practices markedly increased productivity of crops grown on vertisol (Mesfin and Jutzi, 1989; EARO, 1998; Getachew *et al*., 2001; Gezahagn *et al*., 2017b). According to Sinebo (2005), modern varieties have better performance under optimal management conditions but not under stress conditions. Crop genotypes grown in different environments would frequently encounter significant fluctuations in yield performance, particularly when the growing environments are distinctly different, the test genotypes differentially respond to changes in the growing environments or both (Tamene *et al*., 2013). Generally, appropriate seedbed preparation, seeding rate, time of planting and method and depth of sowing are some of the major perquisite to be considered to improve productivity of crops grown on vertisol conditions.

Main effects of species mixtures on oats/vetch mixtures performance

Plant height and DM yield of oats/vetch mixtures vary significantly (P < 0.05) under different drainage conditions (Table 5). Plant height of oats/vetch mixtures ranged from 113.0 to 131.3 cm with a mean of 124.9 cm under different drainage conditions. The result indicated that the highest mean plant height (131.3 cm) was recorded from CI-8251/*V. villosa* mixtures followed by CI-8251/*V. dasycarpa* (128.9 cm) and CI-8251/*V. atropurpurea* (126.2 cm) while CI-8251/*V. sativa* mixtures gave the lowest (113.0 cm) plant height under different drainage conditions. Plant height of oats/vetch mixtures increased by 16.2, 14.1 and 11.7% for CI-8251/*V. villosa*, CI-8251/*V. dasycarpa* and CI-8251/*V. atropurpurea* mixtures, respectively, when compared to mixtures of CI-8251/*V. sativa* grown under different drainage conditions. On the other hand, DM yield of oats/vetch mixtures ranged from 8.92 t/ha to 9.60 t/ha with a mean of 9.14 t/ha under different drainage conditions. The result indicated that relatively better mixtures DM yield was obtained from CI-8251/*V. villosa* followed by CI-8251/*V. sativa* and CI-8251/*V. dasycarpa* while CI-8251/*V. atropurpurea* produced the lowest mixtures DM yield under different drainage conditions. Generally, mixtures of CI-8251/*Vicia villosa* produced better plant height and DM yield under different drainage conditions on vertisols implying that these mixtures had good compatibility and less sensitivity of *V. villosa* for waterlogging problems. The recent study made on vertisol also indicated that vetch species respond differently for various drainage conditions and relatively better DM yield was obtained

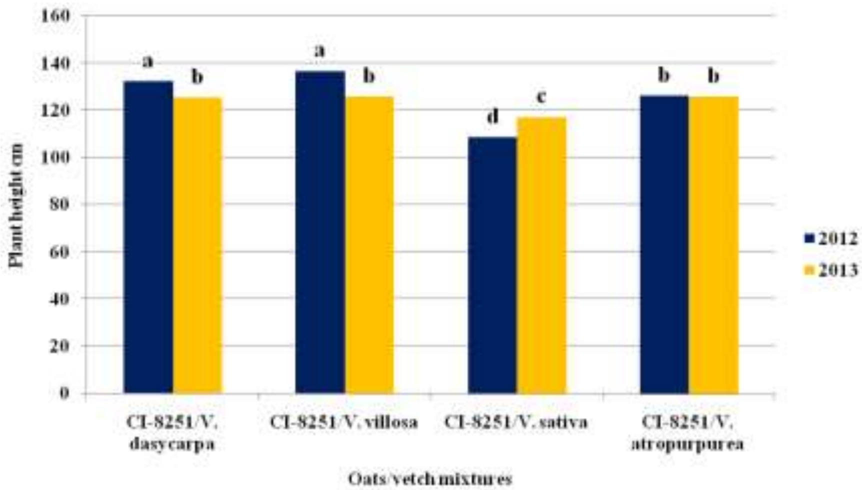

Figure 2. Species by year interactions for plant height of oats/vetch mixtures.

from *V. villosa* when compared to other vetch species on vertisol conditions (Gezahagn *et al*., 2017b). Other research findings also indicated that the performance of oats varieties and vetch species sown in mixtures varies with different varieties and species combinations (Getnet and Inger, 2001). They reported that between oats and vetch there is variations and these characteristics also different under various management practices and environmental conditions (Getnet and Inger, 2001). On waterlogged soils, soil aeration and nutrient absorption are problems, which make plants stunted and decrease growth rate. Moreover, most of the nitrogen added on vertisols was subjected to leaching or denitrification soon after application (Desta, 1988). These factors might have accounted for the low DM yield observed on the vertisols. Soil type was found to be the most important factors affecting biomass yield and hence biomass yield on the red soil was almost double compared to the black soil (Getnet and Inger, 2001). Moreover, oats/vetch mixtures planted on red soil have higher crude protein (CP) content when compared to black soil (Getnet and Inger, 2001). At Debre Zeit, the broad bed and furrow (BBF) resulted in 58 and 73% seed and straw yield increments, respectively, compared to undrained FB conditions because of the reduction in waterlogging damage (Haque *et al*., 1988). At Holetta, CB increased seed yields of faba bean over the FB conditions by about 49% (Desta and Hailu, 1989).

Species by year interaction effects on oats/vetch mixtures performance

Species by year interaction had significant ($P < 0.05$) effect on plant height of oats/vetch mixtures sown with various seeding rates under different drainage conditions of vertisol as indicated in Figure 2. The result revealed that significantly the lowest plant height was recorded for CI-8251/*V. sativa* mixtures in both experimental years. The mixtures plant height of CI-8251/*V. villosa* and CI-8251/*V. dasycarpa* obtained in 2012 cropping season varied significantly when compared to others mixtures in both experimental years. Mixtures plant height varied significantly between the two experimental years, except mixtures of CI-8251/*V. atropurpurea*, indicating critical variations in amount and distribution of rainfall between the two years. On the other hand, species by year interactions effects for DM yield of oats/vetch mixtures sown with different seeding rates under different drainage conditions varied significantly as indicated in Figure 3. The highest DM yield was recorded for CI-8251/*V. dasycarpa* and CI-8251/*V. villosa* mixtures in 2012 cropping season when compared to 2013. Likewise, mixtures of CI-8251/*V. sativa* and CI-8251/*V. atropurpurea* produced better DM yield in the year 2013 when compared to 2012 cropping season. Generally, mixtures of CI-8251/*V. atropurpurea* produced the highest DM yield while CI-8251/*V. dasycarpa* gave the lowest DM yield under different drainage conditions in 2013 cropping season.

Species by location interaction effects on oats/vetch mixtures performance

Plant height of oats/vetch mixtures sown with various seeding rates under different drainage conditions on vertisol was varied significantly ($P<0.05$) by the interactions of species and locations as indicated in Figure 4. All oats/vetch mixtures showed significant difference for plant height between the two locations except CI-8251/*V. sativa* mixtures. Mixtures of CI-8251/*V. dasycarpa* gave the highest plant height at Ginchi while mixtures of CI-8251/*Vicia sativa* produced the lowest plant height at Kuyu site. On the other hand, the interactions of oats/vetch mixtures with locations revealed

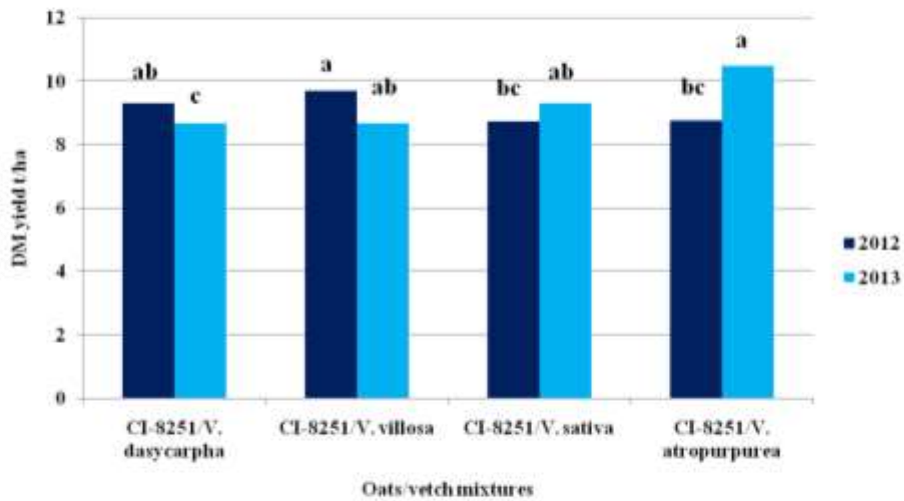

Figure 3. Species by year interactions for DM yield of oats/vetch mixtures.

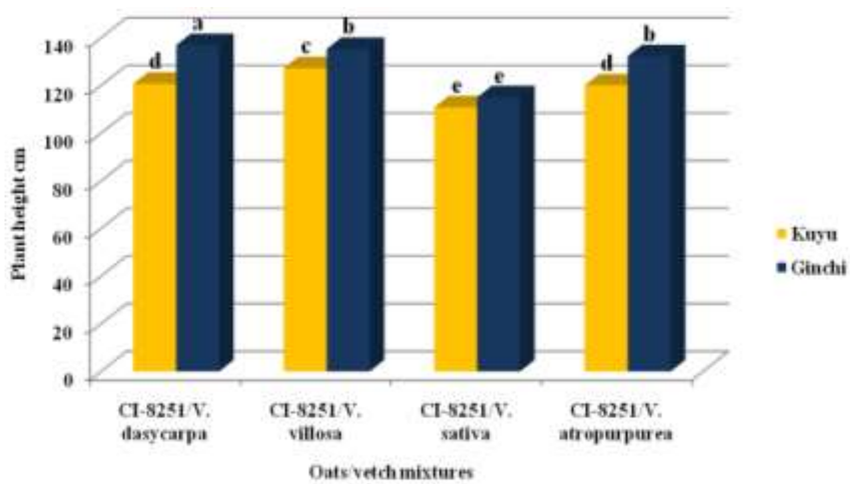

Figure 4. Species by location interactions for plant height of oats/vetch mixtures.

significant variations for DM yield as shown in Figure 5. The DM yields obtained from all oats/vetch mixtures were significantly higher at Ginchi when compared to Kuyu. The highest DM yield was recorded for CI-8251/*V. villosa* followed by CI-8251/*V. dasycarpa* and the lowest recorded from mixtures of CI-8251/*V. atropurpurea* at Ginchi. Likewise, the highest DM yield was obtained from mixtures of CI-8251/*V. villosa* followed by CI-8251/*V. atropurpurea* mixtures while mixtures of CI-8251/*V. dasycarpa* produced the lowest DM yield at Kuyu.

Main effects of mixtures seeding rates on oats/vetch mixtures performance

Plant height and DM yield of oats/vetch mixtures planted with various mixtures seeding rates under different drainage conditions are indicated in Table 6. The result showed that mixtures plant height didn't vary significantly ($P > 0.05$) while significant variation ($P < 0.05$) was observed for DM yield of oats/vetch mixtures. Plant height of mixtures sown with different seeding rates under different drainage conditions ranged from 123.2 to 126.5 cm with a mean of 124.9 cm. The previously recommended (blanket recommendation) seeding rate (75/25 kg/ha for oats/vetch mixtures respectively) was used as a control and gave relatively higher plant height followed by 105/35 kg/ha seeding rate. Low competition for growth resources might be one of the major reason for higher plant height recorded from low (blanket recommendation) seeding rate when compared to other seeding rates. The DM yield of oats/vetch mixtures sown with various seeding rates under different drainage conditions ranged from 8.76 to 9.43 t/ha with a mean of 9.14 t/ha. The highest DM yield was obtained from 105/35 kg/ha seeding rate followed by 135/45 kg/ha and

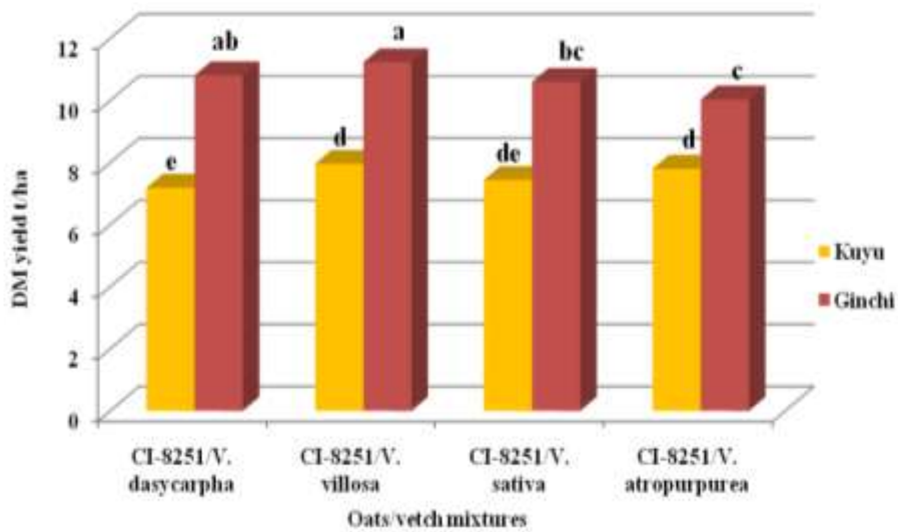

Figure 5. Species by location interactions for DM yield of oats/vetch mixtures.

Table 6. Combined effect of different seeding rates of oats/vetch mixtures grown under different drainage conditions over years and locations

SN	Mixtures seeding rate	Plant height (cm)	DM yield (t/ha)
1	Oats 75 kg/ha + Vetch 25 kg/ha	126.5	8.76^{b}
2	Oats 105 kg/ha + Vetch 35 kg/ha	126.1	9.43^{a}
3	Oats 135 kg/ha + Vetch 45 kg/ha	123.2	9.21^{a}
4	Oats 165 kg/ha + Vetch 55 kg/ha	123.2	9.14^{ab}
	Mean	124.9	9.14
	CV	12.1	20.3
	P-value	0.2173	0.0006

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

165/55 kg/ha seeding rate while the lowest DM yield recorded from the control (75/25 kg/ha) seeding rate. The DM yield of oats/vetch mixtures sown with seeding rates of 105/35, 135/45 and 165/55kg/ha had yield advantages of 7.6, 5.1 and 4.3%, respectively, when compared to the control (75/25 kg/ha) seeding rate. Therefore, oats/vetch mixtures should be sown with seeding rate of 105/35 kg/ha on vertisol conditions while on nitosol it should be planted with previously recommended (75/25 kg/ha) seeding rate. This experiment generally emphasized that soil types based recommendation for seeding rate is very important to improve the productivity of crops grown under different drainage methods on vertisol conditions. Getnet and Inger (2001) also noted that both soil types vary in physical and chemical properties so blanket mixtures seeding rates recommendation (75/25 kg/ha for oats/vetches mixtures respectively) should not be used for both soil types. Therefore, the recommended seeding rate should be used when a crop is sown at normal time to achieve the right plant population for adequate competition with weeds and for better seed yield and quality (Getnet and Gezahagn, 2012).

Seeding rate by location interaction effects for DM yield of oats/vetch mixtures

Seeding rate by location interactions for DM yield of oats/vetch mixtures sown with various seeding rates under different drainage methods on vertisol conditions varied significantly ($P < 0.05$) as shown in Figure 6. The result indicated that all seeding rates of oats/vetch mixtures sown under different drainage methods gave significantly higher DM yield at Ginchi when compared to Kuyu site. The interaction was non-crossover effects this indicates there is no change in ranking order for DM yield performance between the two locations when oats/vetch mixtures are subjected to different seeding rates implying there is no need of site specific recommendation for seeding rates of oats/vetch mixtures for both testing sites. DM yield obtained from the lowest (75/25 kg/ha) oats/vetch mixtures seeding rate at Ginchi site was significantly higher when compared to all other seeding rates at Kuyu. Oats/vetch mixtures sown with seeding rate of 75/25 kg/ha under different drainage conditions on vertisol produced significantly the lowest DM yield at

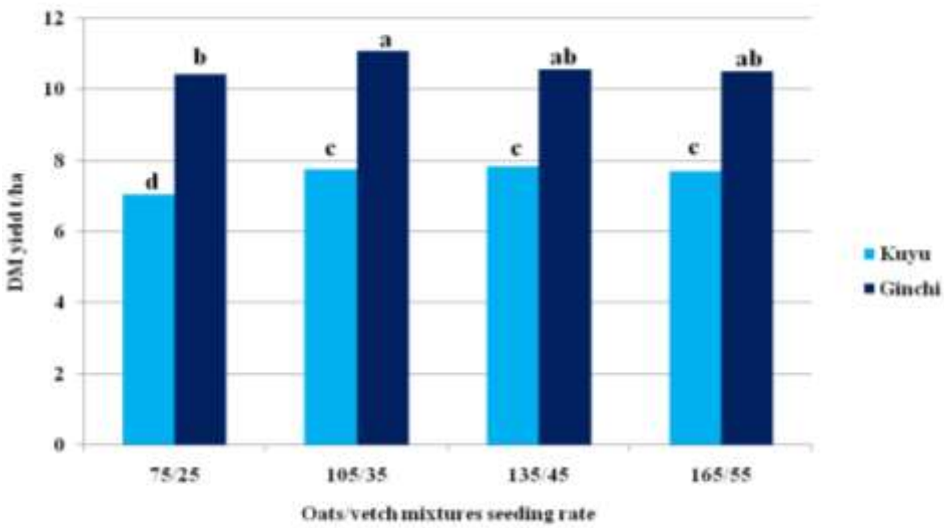

Figure 6. Seeding rate by location interactions for DM yield of oats/vetch mixtures.

Kuyu followed by at Ginchi. Oats/vetch mixtures sown with seeding rate of 105/35 kg/ha produced significantly the highest DM yield at Ginchi when compared to Kuyu site. Relatively warmer climatic conditions, better distribution and less amount of rainfall might be some of the major reasons for getting better DM yield at Ginchi when compared to Kuyu site.

CONCLUSION AND RECOMMENDATION

Relatively better plant height and DM yield were obtained from Ginchi when compared to Kuyu experimental site and the two years had more or less similar plant height and DM yield. The highest mean DM yield was obtained from CB drainage condition followed by RF and FB. The combination of oats/vetch (CI-8251/*V. villosa*) sown with different seeding rates gave better DM yield response under different drainage methods on vertisol conditions. The highest DM yield was obtained from seeding rate of 105/35 kg/ha while seeding rate of 75/25 kg/ha gave the lowest yield under different drainage methods. So, the previously recommended seeding rate (75/25 kg/ha) is appropriate for other soil types not for black soil/ vertisol. Therefore, seeding rate of 105/35 kg/ha is recommended for oats/vetch mixtures grown on vertisol conditions in the central highlands of Ethiopia.

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