Journal of Scientific Agriculture 2024, 8: 51-58
doi: 10.25081/jsa.2024.v8.8955
https://updatepublishing.com/journal/index.php/jsa

Research Article

ISSN: 2184-0261

Evaluation of biomass yield and seed yield of vetch and oats variety mixtures

Gemechis Lencho Yadeta*

Oromia Agricultural Research Institute Sinana Agricultural Research Center, Ethiopia

ABSTRACT

A different species and varieties of forage vetch and oat were identified to successfully adapt and perform in the highlands of Bale. However, their oat-vetch mixture was not evaluated. The study was conducted to evaluate the effect of variety on biomass yield and seed yield of oats and vetch grown in pure stand and mixtures. This experiment was conducted at Sinana Agricultural Research Center, Bale zone, southern Ethiopia, during May 2023. A total of five treatments were developed for sole and mixed stands using two oat varieties and one vetch variety. A trial was arranged in RCBD with five replications. The recorded data are morphological parameters, biomass, tiller, side branch, seedling count and seed yield were calculated and subjected to analysis of variance (ANOVA) following the GLM procedures in SAS version 9.4. The highest dry matter yield (DMY) 18.6 t ha^{-1} was observed by the mixture of Gebisa variety + oat Bonsa variety. Among the mixture treatments, Gebisa variety + oat Bonsa variety had the highest seed yield (2.9 t ha^{-1}) while the pure stand Bona-bas variety had the seed yield (1.28 t ha^{-1}). The dry matter yield (DMY), of mixtures of Gebisa variety + oat Bonsa variety mixtures was better than pure stands. Based on the current result it is concluded that oat Bonsa variety + Gebisa variety mixtures had relatively higher yield biomass. Generally, in the present study on Oat-vetch mixture, there is higher yield biomass so, Animal performance must be tested.

Received: March 20, 2024
Revised: July 15, 2024
Accepted: July 18, 2024
Published: August 06, 2024

***Corresponding author:**
Gemechis Lencho Yadeta
E-mail: lenchoabdibor041@gmail.com

KEYWORDS: Dry matter, Leaf-to-stem, Oat-vetch mixture

INTRODUCTION

Ethiopia has a large livestock population with 70 million cattle, 42.9 million sheep, 52.5 million goats, 2.15 million horses, 10.80 million donkeys, 0.38 million mules, 8.1 million camels, and 57 million poultry (ESS, 2021). Even though the country has the largest livestock population, benefits gained from the sector are not proportional to the available potential due to the existence of various constraints (Alemayehu & Getnet, 2012).

Poor animal nutrition and productivity arising from the inadequate supply and low-quality feed are among the major constraints facing livestock production in developing countries (Feyissa *et al.*, 2015b). Feed shortage in terms of both quantity and quality is the leading problem affecting livestock productivity in Ethiopia (Feyissa *et al.*, 2015a). Similarly, the productivity of animals remained low due to feed shortages and nutritionally unbalanced feed supplies (DARE, 2013). Traditional livestock production system mainly depends upon poor pasturelands and crop residues which are usually inadequate to support reasonable livestock production.

In the Ethiopian highlands, the farming system is characterized by crop-livestock mixed farming systems (Kebede *et al.*, 2017). As a result, residues from cereals are the main source of forage but these are low in protein and have poor digestibility. The production of adequate quantities of good quality dry season forages to supplement crop residues and pasture roughages is the only way to economically overcome the dry season constraints affecting livestock production in Ethiopia.

Forage species such as vetch (*Vicia sativa*) and oat (*Avena sativa*) are high-potential feed sources to fill the gap of feed shortage; which are promising due to their high-quality feeding value and they are also well adapted to drought stress areas (Molla *et al.*, 2018) and well compatible in planting as a mixture.

To alleviate the feed shortage in Ethiopia generally and in study areas, in particular, the establishment of forage crops such as oats cultivated with forage legume is obligatory. Mixed cropping of cereals with forage legumes can improve both the quality and quantity of fodder over pure cereal crops. Nowadays many oat and legume species have been tested and recommended for the different agroecological zones in the country.

Compared to their pure sowing, cereal, and legume mixtures are characterized by a higher total protein yield, more stable yielding, especially in unfavorable habitats, better legume health, and higher nutritional value (Kamalongo & Cannon, 2020; Salama, 2020). Most studies on the production, productivity and compatibility of oats-vetch mixtures were done at high land vertisols and nitisols areas of Ethiopia (Fantahun *et al.*, 2017; Kebede *et al.*, 2017). The current study evaluated the differences in the relative productivity of the mixture of vetch-oats varieties. Therefore, this study was conducted to evaluate biomass yield and seed yield of different vetch-oats varieties grown in pure stand and mixture at the highlands of Ethiopia. The specific objective is to determine the best-performing forage oats and vetch mixture based on biomass yield, seed yield, morphological, and growth performance mixed under Sinana Agricultural Research Center.

MATERIALS AND METHODS

Description of the Study Area

The experiment was conducted at Sinana Agricultural Research Center, located at 40° 12' 0" east longitude, 7° 5' 0" north latitude, at an altitude of 2400 meters above sea level and 463 km southeast of Finfinne (Addis Ababa) in Bale zone and 33 km east of Robe town. Sinana is characterized by bimodal rainfall characteristics. The two seasons are locally called Bona and Ganna. Bona season extends from July to late December and Ganna season from mid-March to August. It has an annual rainfall of 1100 mm and a mean annual temperature of 15 °C (NMA, 2014).

Treatment and Experimental Design

The experiment consists of five treatments of two oat varieties namely (Bonsa and Bona-bas), and one vetch variety namely Gebisa. Oat Bonsa, Bona-bas, and Vetch Gebisa varieties were released (2011) from the Sinana Agricultural Research Center. The experimental treatments were assigned to individual plots using a Randomized Completely Block Design (RCBD) in five replications which were randomly assigned to each experimental unit (Table 1). The plot size was 6.3 m^2 (2.1 m × 3 m). The spacing between blocks and plots was 1.5 m and 1 m, respectively (Aklilu & Alemayehu, 2007). In each plot, there were 7 rows, and seeds were uniformly drilled in rows with intra-row spacing of 30 cm. The seed proportions were calculated based on the recommended seed rates of 75 kg and 25 kg ha^{-1} for the mixture of cropping oats and vetch, respectively (Feyissa *et al.*, 2008). The seed rates for the mixture of oats and vetch were calculated and uniformly drilled in rows at a constant depth of 5 cm.

Table 1: Description of treatment combination and block

Treatment	Combination	Number of Replications
1	Sole oat variety Bona-bas (Acc. No. 1660)	5
2	Sole oat variety Bonsa (Acc. No. 79AB384)	5
3	Sole vetch variety Gebisa (Acc. No. 62632)	5
4	A mixture of oat Bonsa and vetch Gebisa	5
5	A mixture of oat Bona-bas and vetch Gebisa	5
	Total plots	25

Land Preparation, Sowing, and Management Practices

The land selected and allocated for the experiment was plowed three times before the start of the experiment. Then, the plots were uniformly fertilized with NPS at a rate of 100 kg ha^{-1} (63 g/plot) at the beginning of the experiment by broadcasting and then mixed with the upper soil layer using hand rakes (Feyissa *et al.*, 2008). The varieties were sown in May 2023 at the commencement of the rainy season. Weeding manually was conducted three times from the days of emergency up to maturity.

Phonological Parameters

Days to emergency

Data was recorded as some days from the date of sowing to the day when the majority (90%) of the planted seeds emerged just above the ground (Aklilu & Alemayehu, 2007).

Days to forage harvest

Days to forage harvest were recorded from days to planting to the date when plants reach the 50% flowering stage (Aklilu & Alemayehu, 2007). Data on days to 50% blooming stage of two forages were recorded from the net plot area from the date of planting when 50% of the plants' plots reached their respective phonological stage.

Days to 90% physiological maturity

Days to forage seed harvest was recorded as the number of days from the date of sowing to the date when 90% of the plants showed yellowing of leaves, pods, and seed hardening in the pods (Salem *et al.*, 2015).

Growth Parameters

Seedling count

Data was taken two weeks after emergence from the middle rows of each plot. The seedling emergence percentage was calculated using the formula according to (Hartmann *et al.*, 1990).

$$\text{Seedling emergency} = \frac{\text{Total number of emerged}}{\text{Number of seeds planted}} * 100$$

The number of side branch per plant

Data was determined by counting the total number of branches from the main steam of five randomly selected vetch plants from the middle rows of each plot at forage harvesting.

The number of tillers per plant

To assess the tillering performance of the varieties, the plant stand was counted on the 45th day of sowing as described above for seedling count (Aklilu & Alemayehu, 2007). Five oat plants were randomly selected in the middle three rows of each plot to avoid the edge effect and count the number of tillers found from individual plants and then after, the average number of tillers per plant was calculated (Amanuel *et al.*, 2019).

Plant height (cm)

Plant height was determined by measuring the length of sampled plants from the ground level to the top of the plants at the milk stage of oats which is the recommended stage (Kebede *et al.*, 2017) for harvesting of oats-vetch mixtures. Ten plants (5 oats and 5 vetch species) were randomly selected from each plot and their heights were measured in centimeters (cm), then the average value was recorded.

Yield and Yield-Related Parameters

Biomass yield

Oats-vetch mixtures were harvested from the interior rows of each plot at the milk stage of oats which is the recommended stage and vetch at the flowering stage to estimate the fresh biomass yield of the oats-vetch mixture (Kebede *et al.*, 2017). The total biomass was weighed and separated into oats and vetch to estimate yield advantage. The fresh weight was recorded in the field using a top-loading field balance. The fresh sub-samples were measured from each plot and each plant species was separately weighed and chopped into short lengths (2-4 cm) to estimate fresh biomass yield. The fresh subsample of 300 grams of fresh weight was taken from each treatment and dried at 60 °C for 48-72 hrs in an oven for quality determination. A 200 g sub-sample was taken and dried in a forced draft oven at a temperature of 105 °C overnight for total dry matter yield determination (Molla *et al.*, 2018).

The leaf to stem ratio (LSR) of oats and vetch was determined by taking 200 g samples from each plot and then partitioning them into leaf and stem. The fresh leaves and stems were weighed separately and dried in a forced air draft oven at 105 °C for 24 hours. Then the leaf weight was divided by stem weight to determine LSR. The oven-dried samples were reweighed to determine the total dry matter yield calculated.

$$\text{DM yield}(t/ha) = \frac{(10 \text{ x TFW x SSDW})}{(\text{HA X SSFW})} \text{ (Mutegi}\textit{et al.}\text{,2008)}$$

Where:
10 = constant for conversion of yields in kg/m^2 to tone/ha
TFW = total fresh weight from harvesting area (kg)
SSDW = sub-sample dry weight (g)
HA = harvest area (m)
SSFW = sub-sample fresh weight (g)

Crude protein yield (CPY) and neutral detergent fiber (NDFY) of the treatments were further determined as the product of CP and NDF content and herbage DM yield (Starks *et al.*, 2006).

$$\text{Crude protein yield(CPY)}(t/ha) = \frac{\text{DMY } t/ha \text{ *\%CP}}{100}$$

Where:
DMY (t/ha) = dry matter yield ton per hectare
%CP = crude protein content forage.

$$\text{Neutral detergent fiber yield(NDFY)}(t/ha) = \frac{\text{DMY } t/ha \text{ *\%NDF}}{100}$$

Where:
DMY (t/ha) = dry matter yield ton per hectare
%NDF = neutral detergent fiber content of the forage

Plant N uptakes were determined by multiplying the N concentrations of each treatment by their respective dry matter weights (Abreha *et al.*, 2013).

$$\text{Nuptake}\left(\frac{t}{ha}\right) = \frac{\text{\%N*DMY}(t \ \ ha)}{100}$$

Seed yield (t/ha)

Seed yield was determined by harvesting both vetch and oat plants harvested from the middle two rows of each plot at optimum physiological maturity. Then, it was determined by weighing seed from the net plot and expressed at 10% moisture content for vetch and 12.5% for oats using the following formula. Seed yield was calculated using the following (Salem *et al.*, 2015; Amanuel *et al.*, 2019).

$$\text{Seed yield } t/ha = \frac{\begin{array}{c}\text{Seed yield per two middle rows*10*}\\ \text{Sub sample dry weight}\end{array}}{\begin{array}{c}\text{sub sample pre} - \text{drying}\\ \text{weight*harvest area}\end{array}}$$

Thousand seed weight (g)

A thousand seeds were counted from the harvested bulk of seeds per net plot and their weight (g) was determined at 12.5% moisture content for oats and 10% for vetch by using a sensitive balance. Thousand seed weight is also an important yield component that reflects the magnitude of seed development that ultimately affects the final yield of a crop.

Thousand seed weight (g) $= 100 - \text{DMAM} \backslash 100 - \text{CM} * \text{FWTS}$
Where:
DMAM =Dry matter of adjusted moisture % of seeds
CM = Constant moisture adjusted to (10%) for vetch and 12.5 for Oats
FWTS = Fresh weight of 1000 seeds (g)

Statistical Analysis

The data on days of emergence, nodule score, herbage DM yield, number of tillers and side branches, and plant height was subjected to analysis of variance (ANOVA) using the general linear model (GLM) procedure of SAS (2002) version 9.4.

Mean treatment comparisons were done using the Tukey test for variables in which F-values declared a significant difference and differences were considered statistically significant at a 5% level.

The model used was: $Yijk = \mu + ai + bj + eijk$

Yijk = response variable
μ = overall mean
ai = ith treatment effect
bj= jth block effect
eijk = random error

RESULTS AND DISCUSSION

Emergence Percentage

The result for emergence count for both oat and vetch species is indicated in Table 2. The calculated emergence percentage of Vetch Gebisa *Vicia sativa* was 90%. The emergence percentage of the two oat varieties Bona-bas and Bonsa were almost similar which is 90% and 91% respectively. The differences between emergence percentages of both species might be due to the quality of the seed in which some were affected by seed quality attributes. The result of the current finding is in line with Assefa and Kebede (2012) who reported that the germination percentage for Vicia species was 89% to 93% and for Avena species 77% to 93% at different storage durations under room temperature and humidity at Holetta in the high land of Ethiopia.

Effect of Variety on Growth Parameters of Oats and Vetch of Oats-vetch Mixtures

There is a significant difference ($P<0.05$) in plant height for vetch at the blooming stage and oats at the heading stage between the all treatments (Table 3). Oat Bona-bas had maximum mean plant heights of 150.72 cm under mixture and 147.16 cm under pure stand conditions. Oat Bonsa had maximum mean plant heights of 108.8 cm under mixture and 105.08 cm under pure stand conditions. Vetch Gebisa + Oat Bona-bas and Vetch Gebisa + Oat Bonsa achieved the highest plant height of 150.72 cm and the lowest plant height 108.8 cm, respectively. The mixed plot showed higher plant height than the pure stand plots. The highest plant height was under a mixture Bona-bas variety with Gebisa, and the lowest plant height was under pure stand Gebisa variety 52.4 cm and 49.4 cm, respectively. These differences could be caused by the result of moisture conservation by the legumes and competition for sunlight between the plants of the two varieties. This finding is in agreement with that of Seid (2022), who found that the mixed oat variety has a taller plant height than pure stand.

Table 2: The calculated emergence percentage (%) of vetch and oats

Varieties	Emergence (%) of two forages before planting
Oat Bona-bas (*Avena sativa*) (Acc. No. 1660)	90
Oat Bonsa (*Avena sativa*) (Acc. No 79AB384)	91
Vetch Gebisa (*Vicia sativa*) (Acc. No. 62632)	90

Table 3 shows that there was significant variation ($P<0.05$) of tillers per plant between varieties and cropping regimes during the oat flowering stage. The highest number of tillers per plant was found in the Bona-bas variety 8.36 under mixture, whereas the Bona-bas variety under pure stand was the next 7.52 tillers per plant. The mixed Bonsa variety with Gebisa variety had the lowest tillers per plant 5.44. In a pure stand of Bonsa variety, the average mean of 4.92 tillers was noted. In the mixed plot as opposed to the solitary oat plots, there were more tillers per plant for oats. In mixed crops, there was a diversity of the varieties and the suitability of the varieties to the experimental site which could all be the reasons for the variation in the number of tillers. The present result is higher than the finding of Belayneh (2020) who reported that the highest number of tillers was observed in oat 8.20 grown in mixture at Mareka District. The present result is lower than the finding of Amanuel *et al*. (2019) who reported that the highest number of tillers per plant 12.0 followed by 11.0, and 10.7 and the lowest was recorded for the variety 10.3 grown under irrigation conditions in Soddo zuriya district, Wolaita Zone, Ethiopia at 50% heading stage.

The number of side branches per plant in the vetch was significantly ($P<0.05$) influenced by mixture and variety differences (Table 3). There were more side branches per plant in the mixed stand of the Bonsa variety than in the Bona-bas variety. A mixture of vetch with oats (Bona-bas and Bonsa) varieties side branches yielded 7.8 to 12.7 mean values respectively, instead of pure stand 18.72 cropping plots. In the study, the pure stand Gebisa variety had higher side branch capacities than their mixed varieties containing oats. It is most likely that differences in varieties of oats may cause differences in the side branches ability vetch variety. The current result is higher than the result of Molla *et al*. (2018) which stated that the mean number of branches per plant of *Vicia vilosa* 14.57 and *Vicia dasycarpa* 11.43 in the Fogera district.

Table 3: Effects of varieties on plant height, number of tillers, side branch and seedling count

Treatments	PH cm		NTPPO	NSBPPV	SC m^2	
	Oats	Vetch			Oats	Vetch
T1	147.16^a	-	7.52^b	-	118.4^a	-
T2	105.08^b	-	4.92d	-	101^b	-
T3	-	51.16^{ab}	-	18.72^a	-	48^a
T4	108.8^b	49.4^b	5.44^c	12.7^b	59.8d	23.2^b
T5	150.72^a	52.4^a	8.36^a	7.8^c	81^c	23.4^b
Mean	127.99	51.16	6.56	13.073	90.05	31.533
P-value	0.001	0.0467	0.03	0.001	0.001	0.001
CV	4.39	3.19	14.64	11.33	10.22	2.13

PH=plant height (cm), NTPPO=number of tillers per plant oat, SC=seedling count, NSBPPV=number of side branches per plant vetch; T1=Oat Bona-bas (*Avena sativa*); T2=Oat Bonsa (*Avena sativa*); T3=Vetch Gebisa (*Vicia sativa*); T4=Vetch Gebisa (*Vicia sativa*) + Oat Bonsa (*Avena sativa*); T5=Vetch Gebisa (*Vicia sativa*) + Oat Bona-bas (*Avena sativa*); CV=Coefficient of variance

Among the treatments, there were significant differences ($p<0.05$) in seedling numbers for both forage species after two weeks of emergency (Table 3). The highest seedling counts at emergence were observed for those grown in pure stand conditions, whereas those with the lowest seedling counts at emergence were produced in the mixture of vetch Gebisa + Bonsa variety containing a grand mean value for oats and vetch of 90.05 and 31.53 seedlings per m^2, respectively. The current result is higher than that of Belayneh (2020), who reported that the highest seedling counts at emergence for both species were obtained under pure stand and the lowest seedling count at emergence was obtained from the mixture of *Vicia sativa* + *Avena sativa* 5431A with grand mean values of 22.33 and 64.94 seedlings per m^2 for vetch and oats respectively at Jimma, Ethiopia. In line with Fantahun *et al*. (2017), the difference between the highest and lowest counts of seedlings at emergence was 8 seedlings per m^2 for vetch varieties and 126 seedlings per m^2 for oats varieties. There may be differences in seedling count due to seed rate and germination percentage at planting.

Morphological Parameters

Days to emergence

Days to emergence of different varieties of oat and vetch showed significant differences ($P<0.05$) as presented in (Table 4). In pure stand vetch Gebisa variety had the longest day to emerge (11 days). It was recorded that the lowest days of emergence were recorded in both the sole and mixed plots of the Bona-bas variety (7 days). The variations in days to emergence between study varieties may be the result of different varieties and species of oat and vetch. This was attributed to the growing nature of the oat varieties and vetch varieties. This result agrees with the finding of Belayneh (2020) who reported that the longest days to emergence (11 days) for *Vicia sativa* both in sole and when mixed with oats varieties, however the shortest days of emergence (7.33 days) was recorded for *Avena sativa* 15153A in both sole and mixed plots. The current result days to emergence had shorter days than that of Solomon (2016) who reported that the maximum number of days to emergence for legume sole treatments was 10.33 and 11.17, respectively, while the lowest number of days to emergence was 8 for sole cereal treatments in northern Ethiopia.

Days to forage harvest

Analysis of variance revealed that the number of days required for 50% flowering showed a significant difference ($p<0.05$) between varieties and mixed cropping (Table 4). It has been shown in the present study that the oat Bonsa variety and vetch Gebisa variety at 50% flowering in pure stands were 90 and 94.6 days respectively. It might be due to the higher N_2 fixation ability of the vetch variety (Gebisa), which enhances the availability of nutrients. For both species, 50% flowering and milking stage occurred between 105.6 and 106.2 days after the sowing of the oats-vetch mixture and the sole vetch respectively. According to the current result, varietal differences and mixtures can explain the differences in 50% flowering between the species. There was a significant delay in 50% flowering in all mixed crop plots compared to sole cropped plots. Oats in the mixture may have a longer maturity period because of the higher proportion of nitrogen fixed by vetch, which kept their mixed cropped leaves green longer than those in pure stand oats. The current result is comparatively shorter days to forage harvest in vetches than the findings of Belayneh (2020) who reported that Oat *Avena sativa* 15153A and vetch *Vicia sativa* were flowered relatively early 90 and 106.67 days were required after the emergence of the seedlings for forage harvest at Southern Ethiopia. The current result shows that the vetch Gebisa variety mixed with the oat Bona-bas variety stayed green and increased days to forage harvest and compatibility was reasonable compared with the oat Bona-bas variety.

Table 4: Days to emergence, 50% flowering and seed harvest of vetch and oat varieties

Treatments	Days to 90% emergence	Days to heading stage for oats and 50% flowering vetch	Days to seed harvest
T1	7^e	90^c	131.4^d
T2	9^c	90.6^c	128.6^e
T3	11^a	106.2^a	152.6^a
T4	10^b	94.6^b	138.4^c
T5	8^d	105.6^a	142.4^b
Mean	9.00	97.40	138.98
P-value	0.001	0.011	0.001
CV	6.09	2.38	3.44

T1=Oat Bona-bas (*Avena sativa*); T2=Oat Bonsa (*Avena sativa*); T3=Vetch Gebisa (*Vicia sativa*); T4=Vetch Gebisa (*Vicia sativa*) + Oat Bonsa (*Avena sativa*); T5=Vetch Gebisa (*Vicia sativa*) + Oat Bona-bas (*Avena sativa*); CV=Coefficient of variance

Days to forage seed harvest

Days to seed maturity of species follow a similar pattern as days to 50% flowering for the forage variety under consideration (Table 4). The difference in day to seed maturity between forage species and varieties was statistically significant ($P<0.05$). In a pure stand, the oat varieties Bonsa and Bona-bas matured 128 and 131 days after forage sowing, respectively. Vetch Gebisa variety ripened late under sole 152.6, whereas 138.4 to 142.4 days after sowing when mixed with oats. Oats had shorter days to seed harvesting than vetch, similarly, their growth rate was faster than vetch, but vetch Gebisa grew slowly at first and quickly at the end of the growing season, compatibility reducing. Until 40 days, the growth rate of vetch in pure stands was quite close to that of vetch in mixtures. Following this, the mixture vetch could not compete and catch up with the oats, and oat suppression became apparent as the plants developed. The study found that the days to forage seed harvest in oat varieties were substantially longer in the mixed treatment of Vetch Gebisa + oat Bona-bas variety (142.4 days) than in the pure stand of Bona-bas variety (128.6 days). In general, mixed cropping has been demonstrated to increase the number of days until harvest. This could be attributed to moisture conservation from the reduced soil water evaporation supplied by the vetches in the mixed treatments, as well as a reduction in the degree of moisture stress. The result of the present finding is similar to the result of Kebede *et al.* (2017) who reported that mean days to forage seed harvest (151.3 days) for pure stand *Vicia sativa* forages at Ginchi locations. The current study is longer than that of the findings of Kebede *et al.* (2016), who reported that the mean days to forage seed harvest for pure stand *Vicia sativa*, *Vicia narbonensis*, and *Vicia villosa* forages in Holetta and Ginchi locations were 140.81 days. The result of the present finding is the shortest days compared to the result of Belayneh (2020) who reported that the mean days to forage seed harvest is 156 days for mixed forage *Vicia sativa* + *Avena sativa* 5431A forages in southern Ethiopia.

Yield and Yield Related Components

Green forage yield

Table 5 shows statistically significant differences in green forage yields (t ha^{-1}) of the varieties at 50% flowering. The ultimate goal of forage production is to obtain a sustainable biomass that meets reasonable quality standards. Green forage yields were highest with the Bonsa variety mixed with the Gebisa variety (41.5 t ha^{-1}) followed by the Bona-bas variety mixed with the Gebisa variety (36.2 t ha^{-1}) and lowest was Bona-bas pure stand (32.4 t ha^{-1}). Higher green forage yield was achieved by the Bonsa variety mixed, which was 9.1% higher than that of lower green forage yield (Bona-bas). In comparison with other tested oat varieties, the Bonsa variety mixture produced the highest green forage yield because the stem was more leaf. The current result is lower than the finding of Amanuel *et al.* (2019) report Variety CV-SRCP X 80Ab 2291 produced the highest green forage yield (42.7 t ha^{-1}) followed by CV-SRCP X 80 Ab 2806 (36.2 t ha^{-1}) and the lowest was recorded for Lampton (28.9 t ha^{-1}). According to Lodhi *et al.* (2009), the maximum green forage yield (47.6 t ha^{-1}) and minimum (33.3 t ha^{-1}) were obtained from the oat varieties No.725 and CK1, respectively, which were higher than the current finding. This is due to the different varieties of oats in the study area.

Forage dry matter yield

Forage dry matter yield (DM) was shown to differ statistically significant ($p<0.05$) across the treatment groups (Table 5). The mixture of oat Bonsa variety and vetch Gebisa variety produced the highest mean forage DM yield (14.6 t ha^{-1}), whereas pure vetch Gebisa produced the lowest mean forage DM yield (6.0 t ha^{-1}). According to the current results, oat variety Bonsa performed better in herbage DM yield than Bona-bas variety in mixtures. The analysis of the variance conclusion revealed under mixed treatments, the herbage dry matter yield of oat variety was considerably greater DM yield than the corresponding pure stand. The higher number of tillers and greater plant vegetative development shown in mixed plots compared to pure stand oat plots may be the cause of the higher dry matter yield for oat-vetch mixture than pure stand. In contrast, Fantahun *et al.* (2017), reported lower mean herbage dry matter and higher mean herbage dry matter yields at the Debra Zeit Agricultural Research Center (75% oats + 25% vetch and 100% vetch seed proportion, respectively).

Table 5: The effect of variety on GFY, FDMY, SY and TSW of Oats-vetch mixtures

Treatments	GFY (t ha^{-1})	FDMY (t ha^{-1})	SY (t ha^{-1})	TSW (g)	
				Oat	Vetch
T1	32.4d	12.8^{b}	1.2^{c}	37.6^{b}	-
T2	33.8^{c}	12.3^{b}	2.7^{a}	65^{a}	-
T3	20.4e	6.0^{c}	0.9d	-	64^{a}
T4	41.5^{a}	14.6^{a}	2.8^{a}	66.6^{a}	59^{a}
T5	36.2^{b}	14.1^{a}	1.4^{b}	38.4^{b}	55.3^{c}
Mean	32.86	11.96	1.8	51.9	59.4
P-value	0.001	0.001	0.001	0.001	0.01
CV	10.58	7.7	18.68	7.49	5.6

FDMY=Forage dry matter yield; GFY=Green forage yield; SY=Seed yield; TSW=thousand seed weight; T1=Oat Bona-bas (*Avena sativa*); T2=Oat Bonsa (*Avena sativa*); T3=Vetch Gebisa (*Vicia sativa*); T4=Vetch Gebisa (*Vicia sativa*) + Oat Bonsa (*Avena sativa*); T5=Vetch Gebisa (*Vicia sativa*) + Oat Bona-bas (*Avena sativa*); CV=Coefficient of variance

The current result is higher than that of Molla *et al.* (2018), who reported dry matter yield of oat and vetch mixtures was higher at harvesting stage two (4.9 t ha^{-1}), whereas the lowest dry matter yield (3.4 t ha^{-1}) was obtained at harvesting stage one at Fogera District, Ethiopia.

Seed yield

The seed yield in tons per hectare was significantly affected ($P<0.05$) due to species variability and mixed cropping (Table 5). The highest mean seed yields were recorded from mixed Oat Bonsa variety + vetch Gebisa variety (2.8 t ha^{-1}), and the lowest mean seed yields were recorded (1.2 t ha^{-1}) under pure stand. There was a significant difference between the sole cropping and the mixed treatments in terms of seed yield, with the mixed treatments producing by far the highest yield compared to the sole cropping. In oats, yield differences may be attributed to the effective tillers and varietal variability may be attributable. As a result, the current result is similar to the finding of Belayneh (2020) who reported that the mean seed yield under pure stand is lower than mixed treatments.

Thousand seed weight

Thousand seed weights of both vetch and oats varieties show a significant ($P<0.05$) difference among the treatments (Table 5). Under mixed, oat Bonsa variety + vetch Gebisa variety recorded the highest thousand seed weight of 66.6 g, while the pure stand Bona-bas variety recorded the lowest thousand seed weight of 37.6 g. This agronomic trait is important for seed rate determination for both vetch and oat varieties. Different species, mixed cropping, and seed size could account for the difference in thousand seed weight. Assefa (2012) also reported that most of the oat varieties with high grain yield showed higher thousand seed weight. The current result is agreed with the findings of Belayneh (2020) who reported that the highest thousand seed weight 89.3 g was recorded from vetch varieties whereas the lowest thousand seed weight 37.6 g was recorded for oat Avena at Jimma, Ethiopia.

Table 6: Effects of leaf to stem ratio of oats and vetch grown in pure stand and mixtures

Treatments	Leaf to stem ratio	
	Oat	Vetch
T1	0.5302[b]	-
T2	0.93[a]	-
T3	-	0.91[a]
T4	0.99[a]	0.61[b]
T5	0.5306[b]	0.51[c]
Mean	0.74	0.68
p-value	0.001	0.001
CV	11.62	4.42

T1=Oat Bona-bas (*Avena sativa*); T2=Oat Bonsa (*Avena sativa*); T3=Vetch Gebisa (*Vicia sativa*); T4=Vetch Gebisa (*Vicia sativa*) + Oat Bonsa (*Avena sativa*); T5=Vetch Gebisa (*Vicia sativa*) + Oat Bona-bas (*Avena sativa*); CV=Coefficient of variance

Leaf to stem ratio of Oats-vetch mixtures

Effects of oat varieties and vetch variety on leaf to stem ratio and dry matter yield of oats and vetch grown in sole and in mixtures are presented in (Table 6). Leaf to stem ratios of oats were significant ($P<0.05$) among oat varieties. The highest leaf to stem ratio value was 0.99 obtained from oat Bonsa variety mixed + vetch Gebisa variety. In terms of the mean leaf to stem ratio, Bonsa variety in mixture and Bona-bas variety had the highest and lowest ratios, respectively. The current result is higher than the finding of Seid *et al.* (2022) who reported the highest mean leaf to stem ratio from SRCP X 80 Ab 2806 (0.69) mixed with vetch species at Assosa Benishangul-Gumuz Region.

CONCLUSION

The study was conducted at Sinana Agricultural Research Center to evaluate the effects of varieties of oats and vetch in mixture and pure stand on yield and quality and also evaluate their compatibility. Considerable variations exist among the tested varieties indicating the potential for selecting superior varieties for both forage biomass and seed yield. The finding of the study indicates that the highest DM was obtained from the Oats-vetch mixture Bonsa variety + Gebisa variety. The highest seed yield was obtained from the Bonsa variety + Gebisa variety mixture and the Bonsa variety in pure stand respectively. Generally, in the present study Oat-vetch mixture increased the relative yield total of two species of dry matter yield advantage obtained from the mixture compared to their respective pure stand.

RECOMMENDATIONS

The mixture of Bonsa variety + Gebisa variety was the best performed in most agronomic and nutritional parameters at the harvesting stage (50% flowering) and it is recommended for fodder production in Sinana District and related high lands of Bale to fill the dry season feed shortage (through conserved forage) and improve livestock production, reduce fertilizer price (Urea) and productivity, and enhance food security. However, this study was conducted in only one location over a single season therefore it is recommended that the experiment should be conducted over different locations and years to draw more concrete recommendation.

REFERENCES

Abreha, K., Heluf, G., Tekalign, M., & Kindie, T. (2013). Wheat crop response to liming Materials and N and P fertilizers in acidic soils of Tsegede highlands, Northern Ethiopia. *Agriculture, Forestry and Fisheries, 2*(3), 126-135. https://doi.org/10.11648/j.aff.20130203.12

Aklilu, M., & Alemayehu, M. (2007). *Measurements in pasture and forage cropping systems*. Technical manual 18. Addis Ababa, Ethiopia: Ethiopian Institute of Agricultural Research.

Alemayehu, M., & Getnet, A. (2012). The Evolution of Forage Seed Production in Ethiopia. In A. Getnet, D. Mesfin, H. Jean, A. Getachew, M. Solomon, & M. Alemayehu (Eds.), *Forage seed research and development in Ethiopia* (pp. 15-32) Addis Ababa, Ethiopia: Ethiopian Institute of Agricultural Research.

Amanuel, W., Kassa, S., & Deribe, G. (2019). Biomass Yield and Nutritional Quality of Different Oat Varieties (*Avena sativa*) Grown under Irrigation Condition in Sodo Zuriya District, Wolaita Zone, Ethiopia. *Agricultural Research and Technology, 20*(4), 556138.

Assefa, G. (2012). Retrospect and prospects of forage and pasture crops research in Ethiopia. In G. Assefa, M. Dejene, J. Hanson, G. Anemut, S. Mengistu & A. Mengistu (Eds.), *Forage Seed Research and Development in Ethiopia* (pp. 7-14) Addis Ababa, Ethiopia: Ethiopian Institute of Agricultural Research.

Assefa, G., & Kebede, G. (2012). An overview of forage seed quality in Ethiopia. In G. Assefa, M. Dejene, J. Hanson, G. Anemut, S. Mengistu & A. Mengistu (Eds.), *Forage Seed Research and Development in Ethiopia* (pp. 197-210) Addis Ababa, Ethiopia: Ethiopian Institute of Agricultural Research.

Belayneh, T. (2020). *Evaluation of biomass yield, seed yield and chemical composition of different varieties of vetch and oats grown in pure stand and mixture*. Master's Thesis, Jimma University.

DARE. (2013). Department of Agricultural Research and Education. Ministry of Agriculture Government, India.

ESS. (2021). *Agricultural sample survey livestock and livestock characteristics private peasant holdings*. Ethiopia: Ethiopian Statistical Service.

Fantahun, D., Ashenafi, M., Diriba, G., & Buzunesh, T. (2017). The Effect of variety and seed proportions on yield, nutritional quality and compatibility of oats and vetch mixtures. Proceeding of the National Conference (pp. 19-38).

Feyissa, F., Assefa, G., Kebede, G., Mengistu, A., & Geleti, D. (2015a). Cultivated Forage Crops Research and Development in Ethiopia. In A. Yami, G. Assefa & L. Gizachew (Eds.), *Pasture and Rangeland Research and Development in Ethiopia* (pp. 89-118) Addis Ababa, Ethiopia: Proceedings of a workshop organized by Ethiopian Society of Animal Production (ESAP).

Feyissa, F., Kebede, G., & Assefa, G. (2015b). Dynamics in Nutritional qualities of tef and wheat straws as affected by storage method and storage duration in the central highlands of Ethiopia. *African Journal of Agriculture Research, 10*(38), 3718-3725. https://doi.org/10.5897/AJAR2015.9903

Feyissa, F., Tolera, A., & Mengistu, S. (2008). Proportions of morphological fractions of oats (*Avena sativa* L.) as affected by variety and growth stage. *Livestock Research for Rural Development, 20*(6).

Hartmann, H. T., Kester, D. E., Davies, F. T., & Geneve, R. L. (1990). *Plant propagation: Principles and Practices*. (7th ed.). New Jersey, US: Prentice Hall Publishers.

Kamalongo, D. M. A., & Cannon, N. D. (2020). Advantages of bi-cropping field beans (*Vicia faba*) and wheat (*Triticum aestivum*) on cereal forage yield and quality. *Biology Agriculture & Horticulture, 36*(4), 213-229. https://doi.org/10.1080/01448765.2020.1788991

Kebede, G. (2016). Evaluation of vetch species for yield, yield components and herbage quality in the central highlands of Ethiopia. *Academic Research Journal of Agricultural Science Research, 4*(6), 264-278.

Kebede, G., Assefa, G., Feyissa, F., Mengistu, A., Minta, M., & Tesfaye, M. (2017). Determination of appropriate seeding rate for oats/vetch mixtures grown under different drainage conditions of vertisols in the central highlands of Ethiopia. *Journal of Agricultural and Crop*

Research, 5(5), 85-95.

Lodhi, M. Y., Marghazani, I. B., Hamayun, K., & Marri, M. J. (2009). Comparative performance study of different oat varieties under agro-climatic conditions of Sibi. *Journal of Animal and Plant Sciences, 19*(1), 34-36.

Molla, E. A., Wondimagegn, B. A., & Cheko, Y. M. (2018). Evaluation of biomass yield and nutritional quality of Oats–vetch mixtures at different harvesting stages under residual moisture in Fogera District, Ethiopia. *Agriculture and Food Security, 7*(1), 88. https://doi.org/10.1186/s40066-018-0240-y

Mutegi, J. K., Mugendi, D. N., Verchot, L. V., & Kung'u, J. B. (2008). Combining Napier grass with leguminous shrubs in contour hedgerows controls soil erosion without competing with crops. *Agroforestry Systems, 74*, 37-49. https://doi.org/10.1007/s10457-008-9152-3

NMA. (2014). *National Meteorological Agency.* Addis Ababa, Ethiopia.

Salama, H. S. A. (2020). Mixture cropping of berseem clover with cereals to improve forage yield and quality under irrigated conditions of the Mediterranean basin. *Annals of Agricultural Sciences, 65*(2), 159-167. https://doi.org/10.1016/j.aoas.2020.09.001

Salem, M., Zamir, M. S. I., Haq, I., Irshad, M. Z., Khan, M. K., Asim, M., Zaman, Q., Ali, I., Khan, A., & Rehman, S. (2015). Yield and Quality of Forage Oat (*Avena sativa* L.) Cultivars as Affected by Seed Inoculation with Nitrogenous Strains. *American Journal of Plant Sciences, 6*, 3251-3259. https://doi.org/10.4236/ajps.2015.619316

Seid, K. A. (2022). *Effect of Variety and Seed Proportions on Yield and Nutritional Quality of Oats-vetch Mixtures Grown on Acidic Soils at Assosa, Benishangul-Gumuz Region*. Master's Thesis, Hawassa University.

Solomon, E. (2016). *Evaluating the productivity and economic benefits of cereal-legume intercropping with and without supplementary irrigation in the semi-arid highlands of Tigray, Ethiopia*. M.Sc. Thesis. Mekelle University of Agriculture.

Starks, P. J., Zhao, D., Philips, W. A., & Coleman, S. W. (2006). Herbage mass, nutritive value and canopy spectral reflectance of Bermuda grass. *Grass and Forage Science, 61*(2), 101-111. https://doi.org/10.1111/j.1365-2494.2006.00514.