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 nitisol 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. 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 (Bona-bas and Bona-bas), and one vetch variety namely Gebisa. Oat Bona-bas, 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 m² (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**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Combination</th>
<th>Number of Replications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sole oat variety Bona-bas (Acc. No. 1660)</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>Sole oat variety Bona-bas (Acc. No. 79AB384)</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>Sole vetch variety Gebisa (Acc. No. 62632)</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>A mixture of oat Bona-bas and vetch Gebisa</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>A mixture of oat Bona-bas and vetch Gebisa</td>
<td>5</td>
</tr>
<tr>
<td>Total plots</td>
<td></td>
<td>25</td>
</tr>
</tbody>
</table>

**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).

\[
\text{Seedling emergency} = \frac{\text{Total number of emerged}}{\text{Number of seeds planted}} \times 100
\]

**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 fresh biomass yield. The fresh subsamples 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.

\[
\text{DMY (t/ha)} = \frac{(10 \times \text{TFW} \times \text{SSDW})}{(\text{HA} \times \text{SSFW})} \]  

(Mutegeietal, 2008)

Where:

- \(10\) = constant for conversion of yields in kg/m² to tone/ha
- \(\text{TFW}\) = total fresh weight from harvesting area (kg)
- \(\text{SSDW}\) = sub-sample dry weight (g)
- \(\text{HA}\) = harvest area (m²)
- \(\text{SSFW}\) = 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).

\[
\text{Crude protein yield(CPY)(t/ha)} = \frac{\text{DMY (t/ha)} \times \%CP}{100}
\]

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

Where:

- \(\text{DMY (t/ha)}\) = dry matter yield ton per hectare
- \(\%\text{CP}\) = crude protein content forage.
- \(\%\text{NDF}\) = 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).

\[
\text{N uptake (t/ha)} = \frac{\%\text{N} \times \text{DMY (t/ha)}}{100}
\]

**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).

\[
\text{Seed yield per two middle rows*10^9} = \frac{\text{Sub sample dry weight}}{\text{Sub sample pre-drying weight} \times \text{harvest area}}
\]

**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.

\[
\text{Thousand seed weight (g)} = 100 - \text{DMAM} \times 100 - \text{CM} \times \text{FWTS}
\]

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: 

\[ Y_{ijk} = \mu + a_i + b_j + e_{ijk} \]

\[ Y_{ijk} = \text{response variable} \]
\[ \mu = \text{overall mean} \]
\[ a_i = \text{ith treatment effect} \]
\[ b_j = \text{jth block effect} \]
\[ e_{ijk} = \text{random error} \]

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 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 8.56 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 Bona-bas 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 2: The calculated emergence percentage (%) of vetch and oats

<table>
<thead>
<tr>
<th>Varieties</th>
<th>Emergence (%) of two forages before planting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oat Bona-bas (<em>Avena sativa</em>)</td>
<td>90</td>
</tr>
<tr>
<td>Oat Bonsa (<em>Avena sativa</em>)</td>
<td>91</td>
</tr>
<tr>
<td>Vetch Gebisa (<em>Vicia sativa</em>)</td>
<td>90</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Treatments</th>
<th>PH cm</th>
<th>NTPPO</th>
<th>NSBPPV</th>
<th>SC m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oats</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vetch</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>147.16⁴</td>
<td>-</td>
<td>7.52⁴</td>
<td>-</td>
</tr>
<tr>
<td>T2</td>
<td>105.08⁴</td>
<td>-</td>
<td>4.92⁴</td>
<td>-</td>
</tr>
<tr>
<td>T3</td>
<td>-</td>
<td>51.16⁴</td>
<td>-</td>
<td>18.72⁴</td>
</tr>
<tr>
<td>T4</td>
<td>108.8⁴</td>
<td>49.4⁴</td>
<td>5.44⁴</td>
<td>12.7⁴</td>
</tr>
<tr>
<td>T5</td>
<td>150.72⁵</td>
<td>52.4⁵</td>
<td>8.36⁵</td>
<td>7.8⁵</td>
</tr>
<tr>
<td>Mean</td>
<td>127.99⁵</td>
<td>51.16⁵</td>
<td>6.56⁵</td>
<td>13.07³</td>
</tr>
<tr>
<td>P-value</td>
<td>0.001</td>
<td>0.0467</td>
<td>0.03</td>
<td>0.001</td>
</tr>
<tr>
<td>CV</td>
<td>4.39</td>
<td>3.19</td>
<td>14.64</td>
<td>11.33</td>
</tr>
</tbody>
</table>

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* 5451A 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**

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

$^{a, b, c, d, e}$ CV = Coefficient of variance

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 Bona-bas 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 Bona-bas variety mixed, which was 9.1% higher than that of lower green forage yield (Bona-bas). In comparison with other tested oat varieties, the Bona-bas 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 CKI, 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 Bona-bas 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 Bona-bas 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).

#### 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 Bona-bas 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 Bona-bas 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 59.3 g was recorded from vetch varieties whereas the lowest thousand seed weight 37.6 g was recorded for oat Avena at Jimma, Ethiopia.

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

<table>
<thead>
<tr>
<th>Treatments</th>
<th>GFY (t ha(^{-1}))</th>
<th>FDMY (t ha(^{-1}))</th>
<th>SY (t ha(^{-1}))</th>
<th>TSW (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oat</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>32.44</td>
<td>12.8</td>
<td>1.2</td>
<td>37.6</td>
</tr>
<tr>
<td>T2</td>
<td>33.8</td>
<td>12.3</td>
<td>2.7</td>
<td>65</td>
</tr>
<tr>
<td>T3</td>
<td>20.4</td>
<td>6.0</td>
<td>0.9</td>
<td>64.4</td>
</tr>
<tr>
<td>T4</td>
<td>41.5</td>
<td>14.6</td>
<td>2.8</td>
<td>66.6</td>
</tr>
<tr>
<td>T5</td>
<td>36.2</td>
<td>14.1</td>
<td>1.4</td>
<td>38.4</td>
</tr>
<tr>
<td>Mean</td>
<td>32.86</td>
<td>11.96</td>
<td>1.8</td>
<td>51.9</td>
</tr>
<tr>
<td>P-value</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.01</td>
</tr>
<tr>
<td>CV</td>
<td>10.58</td>
<td>7.7</td>
<td>18.68</td>
<td>7.49</td>
</tr>
</tbody>
</table>

FDMY = Forage dry matter yield; GFY = Green forage yield; SY = Seed yield; TSW = thousand seed weight; T1 = Oat Bona-bas (*Avena sativa*); T2 = Oat Bona-bas (*Avena sativa*); T3 = Vetch Gebisa (*Vicia villosa*); T4 = Vetch Gebisa (*Vicia villosa*) + Oat Bona-bas (*Avena sativa*); T5 = Vetch Gebisa (*Vicia villosa*) + Oat Bona-bas (*Avena sativa*); CV = Coefficient of variance
effects of leaf to stem ratio of oats and vetch grown in pure stand and mixtures

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Leaf to stem ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oat</td>
<td>Vetch</td>
</tr>
<tr>
<td>T1</td>
<td>0.5302*</td>
</tr>
<tr>
<td>T2</td>
<td>0.93*</td>
</tr>
<tr>
<td>T3</td>
<td>-</td>
</tr>
<tr>
<td>T4</td>
<td>0.99a</td>
</tr>
<tr>
<td>T5</td>
<td>0.5306e</td>
</tr>
<tr>
<td>Mean</td>
<td>0.74</td>
</tr>
<tr>
<td>p-value</td>
<td>0.001</td>
</tr>
<tr>
<td>CV</td>
<td>11.62</td>
</tr>
</tbody>
</table>

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 (Urca) 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.

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