***Original research papers***

# Forage Potential of Alfalfa with Oats and Barley in Sole and Intercropping Systems

## ABSTRACT

Production of ~~planted~~ pastures with high energy and protein levels remains a challenge during winter months for livestock. Field trials were conducted to investigate the effects of cropping systems using intercropping (alfalfa + oat and alfalfa + barley) and monocropping (alfalfa, oat and barley) on plant height, yield and quality characteristics. Furthermore, to study the competition experienced by legume and cereals when planted in a mixture. The field trial was carried out in a randomized complete block design ~~(RCBD)~~ with five treatments including sole oat, sole barley and sole alfalfa, alfalfa + oat intercropping and alfalfa + barley intercropping and three replicates. The study was conducted at the Experimental Farm of the National University of Lesotho for two growing seasons during the winter seasons of 2015 and 2016. The results revealed that intercropping increased yields of forage crops than monocrops. Intercropping significantly increased protein levels and reduced fibre concentrations. In intercropping competition indices, land equivalent ratios ~~(LER's)~~ indicated yield advantages for intercropping. Relative crowding coefficient ~~(K)~~ and aggressivity ~~($A_c$)~~ values showed significant advantages of cereal over legume indicating legume was less competitive than cereal. ~~In summary~~, intercropping system was more productive than respective monocrops.

*Keywords: forage; ~~intercropping;~~ yield; quality; competition indices.*

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## ABBREVIATIONS

*A – Aggressivity*
*ADF – Acid detergent fibre*
*ANOVA – Analysis of variance*
*CP – Crude protein*
*D – Days after emergence*
*DM – Dry matter*
*K – Relative crowding coefficient*
*LER – Land equivalent ratio*
*LSD – Least Significant Difference*
*N – Nitrogen*
*NDF – Neutral detergent fibre*

## 1. INTRODUCTION

Intercropping is system including two or more crop species sown in the same time and growing together on the same field [1]. Intercropping of legumes together with cereals for food or forage is used in many parts of the world and has shown great potential in many ways. ~~Intercrops~~ have potential on crop productivity by reducing weed pressure, sustaining plant health and improving dry matter yields [2]. ~~Intercrops~~ sustain fertility status of soil and the possibility of nitrogen accumulation from the leguminous plants to other plants in the soil. Biological fixation of nitrogen is completed by two nitrogen fixing bacteria namely free living bacteria in the soil and symbiotic relationship bacteria which live in the leguminous plant roots enriching surrounding soil with usable nitrogen for cereal plants [3].

Cereal-legume combinations are often used for forage and as cover crops. On animal husbandry, legume-cereal mixtures may be interesting forage harvested for green ~~fodder~~ and maintenance of continuity of feed supply [4]. In other studies, winter grain like rye and wheat combined with a leguminous plant as cover crop. Intercrops protect soil from erosion, help improve soil tilth, and left as dead ~~mulch~~ at the soil surface. Very often the legume provides nitrogen, while the cereal produces organic matter [5]. Some research indicates that legume plants like clover fix more nitrogen into plant-usable form when grown with cereals such as grasses than when planted in a pure stand [6]. Intercrops including legumes are known to use natural resources well and enhance forage than cereal sole cropping [7].

However, in Southern African countries in particular, Lesotho, intercropping of legume and cereals mixture for production of forage is not a common cropping system in winter season. Monocultures of leguminous plants or cereal crops are rarely used for forage and do not provide satisfactory results for ~~fodder~~ production [8]. In particular, production of forage from cereals is usually lower than that required to meet satisfactory nutritional requirements for ruminant animals. Among causes of declining livestock productivity in Lesotho are the deteriorating communal rangelands, low use of planted forages and low quality feeds in winter and spring season. Ruminant animals often face green forage scarcity during winter and spring months and thus have to survive on cereal residues of previous plants including maize straw and sorghum stalk which are not rich source of digestible nutrients.

Intercropping systems may contribute significantly to the winter and spring season diet of animals [9]. Other studies reported the benefits of growing leguminous plants together with cereal crops in winter months. Intercrops including alfalfa legume and cereals like oat and barley are the important winter forage for the sustenance of livestock. Studies have shown that nutritive value and yield of forage is high when produced in cereal legume mixtures [10; 11]. Cereal crops provide with sufficient amount of carbohydrate, while legumes are efficient in increasing protein and mineral content of forage which is necessary for livestock health and productivity.

Alfalfa (*Medicago sativa* L.) is herbaceous legume that has great growth productivity and good ~~fodder~~ recovery after cutting [12]. Alfalfa has ability to add nitrogen to the soil and store energy in the root crown that helps the buds in a quick re-growth which results in high yield [13]. ~~Alfalfa~~ is most important and profitable legume used for production of fodder mainly in intercrops combinations. Mixtures of alfalfa legumes with cereals forage (rye) greatly improve minerals and decrease the prevalence of pasture ~~bloat~~ [14]. Alfalfa has ability to adapt to various environmental conditions and tolerates low temperatures. It was stated that alfalfa and wheat in intercropping system in winter months increased yield, improved growth, reduced weeds, made a better soil coverage and keep it from erosion [15].

Oat plant (*Avena sativa* L.) is forage crop planted primarily for grain and ~~fodder~~, and often grown with a leguminous plant [16]. Oats form an excellent combination and produced high yields, forage quality and minerals when planted along with other winter season legume crops including vetch (*Vicia sativa*) and senji (*Indian clover*) [17]. Studies have shown that some intercropping systems such as vetch (*Vicia sativa*) – oats intercropping have a great potential for improving nutritive value of forage compared to sole cropping [18], whereas other intercropping systems such as berseem (*Trifolium alexandrinum*)–oats intercropping protect soil from erosion, limit weed population and enhance forage productivity [19; 20]. Oats–shaftal (*Persian clover*) intercropping has been shown to reduce diseases, suppress weeds, and improve the nutritive (protein) value of crop compared to oats alone [21].

Barley plant (*Hordeum vulgare L.*) is a leafy forage species and produce valuable ~~fodder~~ for livestock. Barley can be conserved in the form of hay or silage and used later when pastures become unproductive [22]. In forage cropping system, barley forage has been planted in mixture with a legume such as berseem (*Trifolium alexandrium*) and Persian clover (*Trifolium resupinatum*) and improved ~~fodder~~ production [23]. Studies have shown that berseem clover and barley mixture produced higher forage productivity and nutritive value than sole barley [24]. Intercropping barley with vetch produced greater yields and nutritive value higher than either cereal or legume crop alone [25]. In this study, the hypothesis was that cropping systems impacted forage production mainly through influencing nutritive value composition and plant growth attributes. This study was therefore, conducted to determine forage yield potential and nutritive value profile of alfalfa with oats and barley cultivars at four growth stages in intercropping and sole cropping systems, and to study the influence of intercropping system on growth rate of cereal–legume species planted in the mixtures.

## 2. MATERIALS AND METHODS

### 2.1 Site Description

The study was conducted at the Experimental Farm of the National University of Lesotho (29°45'S; 27°72'E) for two growing seasons during the winter seasons of 2015 and 2016. The field trial was established on a well-drained sandy clay loam soil with medium to coarse textured whose characteristics are presented on Table 1. Weather data during the experimental period for two growing seasons is given in Table 2.

**Table 1. Pre-plant soil nutrient analysis (0-40 cm) at the experimental area**

| Year | N | P | K | Ca | Mg | Fe | Mn | pH | Organic Matter |
|---|---|---|---|---|---|---|---|---|---|
| | mg/kg | | | | | | | | (g/kg) |
| 2015 | 82 | 21 | 101 | 1.35 | 0.32 | 7.2 | 3.8 | 6.8 | 8.9 |
| 2016 | 84 | 19 | 104 | 1.32 | 0.43 | 8.1 | 3.2 | 6.5 | 9.9 |

**Table 2. Total rainfall and average temperature per month during experimental period**

| Month | Rainfall (mm) | | Temperature (°C) | |
|---|---|---|---|---|
| | 2015 | 2016 | 2015 | 2016 |
| January | 10.5 | 19 | 32.2 | 44.4 |
| February | 14.6 | 9.7 | 30.5 | 28.6 |
| March | 20.9 | 104 | 27.1 | 24.2 |
| April | 11.3 | 3.3 | 20.2 | 23.1 |
| May | 8.7 | 5.8 | 19.5 | 22.8 |
| June | 2.1 | 7.3 | 14.6 | 15 |
| July | 3.2 | 0 | 15.2 | 17.2 |
| August | 6.1 | 13.4 | 17.6 | 22.2 |
| September | 4.2 | 8.5 | 21.8 | 25.4 |
| October | 11.5 | 5.33 | 26.7 | 27.4 |
| November | 7.3 | 20.4 | 29.4 | 26.5 |
| December | 18.5 | 3.2 | 30.2 | 31.4 |

## 2.2 Forage Management and Experimental Design

The field trial comprised of alfalfa, barley and oats planted in pure stands and intercropping alfalfa legume with barley and oats plants. Seedbed was prepared with tractor disc harrow. Animal manure was applied at the rate of 70kgha$^{-1}$ and incorporated into the soil before planting to reflect the common practice. Forage seeds were planted after soil tillage. Seeding rates used for oat, barley and alfalfa crop were sown at rate of 80, 100 and 25 kgha$^{-1}$ respectively. In mixture combinations, the seed of component forage crops was homogenised at 50:50 ratios before planting. The sole crop and intercrop treatments were established in rows spaced 30 cm apart within 10m by 20m plots; the intercrops of alfalfa with oats and barley were planted in alternate rows with the same row spacing done with a single row drill. Alfalfa seed was inoculated with rhizobia to ~~encourage~~ biological nitrogen fixation. The field trial was carried out in a randomized complete block design (RCBD) with five treatments including sole oat, sole barley and sole alfalfa, alfalfa + oat intercropping and alfalfa + barley intercropping and three replicates. Supplementary irrigation was not applied after days of sowing. Rainfall and temperature recorded are presented in Table 2 during the forage crop growth period.

## 2.3 Forage Measurements

### 2.3.1 Plant Height

The plant height was measured at the major growth stages (tillering, ~~booting~~, flowering and ~~ripening)~~ using disc pasture meter by averaging nine readings recorded inside a 2m x 2m square quadrat.

### 2.3.2 Forage Yield

Dry matter (DM) was measured at the major growth stages by harvesting aboveground materials within the 4m$^2$ quadrat randomly sampled in each plot using manual shears. Forage samples of biomass for alfalfa, oat and barley species from each plot were oven dried at 80°C for at least 48 h to measure the dry matter yield.

### 2.3.3 Forage Quality

A second set of random samples of biomass for forage species of each plot was taken at each major growth stages to measure the forage quality; crude protein (CP), acid detergent fibre (ADF) and neutral detergent fibre (NDF) in the Department of Animal Science Laboratory. CP based on DM was calculated by multiplying the Nitrogen (N) content by 6.25 determined using Kjeldahl method [26]. NDF based on DM was measured by boiling a forage sample using neutral detergent under neutral pH conditions. ADF was measured using acid detergent under low pH condition [27].

### 2.3.4 Intercropping Competition Indices

Land equivalent ratio (LER), the relative crowding coefficient (K) and the aggressivity (A) were calculated to determine the impact of competition between the legume and cereal in a mixture stands. LER shows the efficiency of intercropping compared to sole cropping for use of environmental resources. When LER is lower than one the intercropping have not improved species productivity, whereas, when LER is greater than one the intercropping improved the productivity of the intercropped species [28]. The LER was calculated according to the following equation:

$$\mathrm{LER} = \left(\frac{Y_{LI}}{Y_L}\right) + \left(\frac{Y_{CL}}{Y_C}\right)$$

Where Y is the yield per unit area, $Y_L$ and $Y_C$ are the yields of legume (alfalfa) and cereal (oat or barley), respectively, as monocrops and $Y_{LI}$ and $Y_{CI}$ are the yields of legume (alfalfa) and cereal (oat or barley), respectively, as intercrops.

The relative crowding coefficient (K) measures the relative dominance of one species in a mixture stands. There is no competition when K is equal to one, the species is less competitive when K is lower than one and the species is more competitive in resource use when K is greater than one [29]. The K was calculated with the following equation:

$$K_L = \frac{Y_{LI} Z_{CI}}{(Y_L - Y_{LI}) Z_{LI}}$$

$$K_C = \frac{Y_{CI} Z_{LI}}{(Y_C - Y_{CI}) Z_{CI}}$$

Where, $Z_{LI}$ is the sown proportion of Legume (alfalfa) in mixture stands and $Z_{CI}$ the sown proportion of cereal (oat or barley) in mixture stands.

Aggressivity measures the competition between two different plant species. Both plants are equally competitive if $A_c$ is equal to zero. The cereal is the dominated species if $A_c$ is negative. The cereal species is dominant if $A_c$ is positive [29]. The aggressivity is derived from the following equation:

$$\text{Aggressivity of Legume (alfalfa) } A_L = \left(\frac{Y_{LI}}{Y_L Z_{LI}}\right) - \left(\frac{Y_{CI}}{Y_C Z_{CI}}\right)$$

$$\text{Aggressivity of Cereal (oat or barley) } A_C = \left(\frac{Y_{CI}}{Y_C Z_{CI}}\right) - \left(\frac{Y_{LI}}{Y_L Z_{LI}}\right)$$

### 2.4 Statistical Methods

Statistical Analysis System proc mixed procedure was used for data analysis [30]. Analysis of variance (ANOVA) was performed to measure the effects of intercropping and sole cropping treatments on productivity of forage. Treatment means were separated using a Fisher's protected Least Significant Difference (LSD) test and differences were considered significant at P≤0.05. Mean comparison was conducted using Duncan multiple range test.

## 3. RESULTS AND DISCUSSION

### 3.1 Forage growth and yield attributes

#### 3.1.1 Plant Height

Plant height recorded at different forage growth stages showed significant differences among cropping system treatments in Table 3. In 2015, maximum plant height was attained by intercropping treatments alfalfa + oat (55.7cm) and alfalfa + barley (54.5cm) compared to monoculture treatments oats alone (52.5 cm), barley alone (51.7cm) and the lowest by alfalfa alone (33.9cm). In 2016, plant height was significantly higher in intercropping treatments than in monoculture treatments. Plant height is a major parameter of crop productivity that maximizes the use of the climatic and surface environmental resources available, especially light, carbon dioxide, water and nutrients, allowing the production of maximum crop yield [31]. From the results, it appeared that the height character in intercropping is mainly higher than monoculture which could be the result of efficient utilization of climatic and environmental resources and minimum competition among the plants of different species; legume and cereal. There is possibility that the alfalfa legume may have produced and shared biologically fixed nitrogen with its oat and barley cereals. These results are similar with the findings of other studies, who reported the highest plant height in mixture stand than pure stand [7; 32; 4].

**Table 3. Plant height of alfalfa, oat and barley monocultures and intercrops of alfalfa with oat and barley at different forage growth stages during two winter seasons 2015 and 2016**

| Cropping systems | Plant growth stages (cm) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tillering (30d) | | Jointing (50d) | | Flowering (90d) | | Ripening (110d) | | Height mean | |
| | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 |
| Sole alfalfa | 12.4b | 14.5b | 22.1b | 20.9c | 42.8d | 39.1c | 58.2d | 56.8d | 33.9c | 32.8c |
| Sole oat | 15.2ab | 17.9a | 31.4a | 27.2b | 71.2b | 70.8b | 92.3c | 90.6c | 52.5b | 51.6b |
| Sole barley | 16.6a | 18.1a | 30.1a | 26.6b | 68.5c | 68.2b | 91.5c | 90.8c | 51.7b | 50.9b |
| Alfalfa + Oat | 16.8a | 18.3a | 31.8a | 33.1a | 75.6a | 79.1a | 98.4a | 99.7a | 55.7a | 57.6a |
| Alfalfa + Barley | 17.2a | 18.8a | 32.3a | 31.9a | 72.8b | 73.9b | 95.8b | 97.9b | 54.5a | 55.6a |
| Standard Error (±) | 1.07 | 1.12 | 0.75 | 1.53 | 1.17 | 1.84 | 1.97 | 1.89 | 1.75 | 1.49 |

d – Days after emergence. Means in the same column followed by different letters differ significantly at P≤0.05.

### 3.1.2 Forage Yield

Forage dry matter yield recorded at different growth stages of the monoculture and intercropping system is presented in Table 4. There were significant differences among the forage dry matter yield at different plant growth stages for the two consecutive years. In 2015, alfalfa + oat produced the greatest forage yield at 39.2 tha$^{-1}$ followed by alfalfa + barley at 37.8 tha$^{-1}$, sole oat at 36.3 tha$^{-1}$, sole barley at 34.9 tha$^{-1}$ and sole alfalfa the lowest at 32.8 tha$^{-1}$. In 2016, forage dry matter was significantly higher in alfalfa + oat and alfalfa + barley than sole oat, sole barley and sole alfalfa. Sole oat, sole barley and sole alfalfa had forage dry matter yield decreased from 36.3 tha$^{-1}$, 34.9 tha$^{-1}$ and 32.8 tha$^{-1}$ in 2014 to 35.8 tha$^{-1}$, 33.7 tha$^{-1}$ and 31.6 tha$^{-1}$ respectively in 2016, this could be partly due to their continuous planting on the same area for two consecutive years. Forage intercropping systems showed significant advantages in dry matter yield over monocultures. This effect is likely related to niche differentiation in intercropping in spatial resources use; leaves for light and roots for water, which made intercrops able to utilize natural resources at different times during different growth stages. Intercrops were also effective as suppressing weeds. There was possibility that the alfalfa legume may have released the fixed nitrogen to oat and barley cereal counterpart. Leguminous plant in mixtures of cereal + legume usually has direct benefits of nitrogen fixation in root nodules and contributed to soil fertility which was used by companion as well as subsequent crops [33]. Previous studies reported a similar response of more forage yield produced from cereal-legume mixtures than sole cereal/legume [34; 35; 36].

**Table 4. Forage yields of alfalfa, oat and barley monocultures and intercrops of alfalfa with oat and barley at different plant growth stages during two winter seasons 2015 and 2016**

| Cropping systems | Plant growth stages (tha$^{-1}$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tillering (30d) | | Jointing (50d) | | Flowering (90d) | | Ripening (110d) | | Yield mean | |
| | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 |
| Sole alfalfa | 20.8a | 22.8a | 28.5b | 28.8b | 40.3d | 36.1c | 41.7c | 38.5c | 32.8c | 31.6c |
| Sole oat | 21.2a | 23.2a | 29.1a | 29.9b | 46.2c | 44.9b | 48.9ab | 45.1b | 36.3b | 35.8b |
| Sole barley | 20.8a | 22.3a | 27.2b | 28.1b | 45.7c | 42.1b | 46.2b | 42.4b | 34.9b | 33.7bc |
| Alfalfa + Oat | 21.1a | 23.7a | 30.7a | 32.5a | 51.5a | 53.7a | 53.4a | 55.7a | 39.2a | 41.1a |
| Alfalfa + Barley | 21.9a | 22.9a | 29.6a | 31.4a | 48.7b | 51.6a | 50.9b | 54.9a | 37.8ab | 40.2a |
| Standard Error (±) | 0.32 | 0.89 | 1.44 | 1.85 | 0.96 | 1.07 | 1.56 | 1.91 | 0.75 | 1.87 |

d – Days after emergence. Means in the same column followed by different letters differ significantly at P≤0.05.

## 3.2 Forage Quality

### 3.2.1 Crude Protein (CP)

Crude protein of forage mixtures and pure stands at four growth stages is presented in Table 5. Forage crude protein data indicated that there was significant difference among treatments for two consecutive years. In 2015, maximum crude protein content (21.1 $gkg^{-1}$) was obtained from alfalfa + oats~~, followed by~~ alfalfa + barley, sole alfalfa, sole oats and the lowest by sole barley. In 2016, forage crude protein was significantly higher in alfalfa + oat, alfalfa + barley, sole alfalfa than in sole oat and sole barley. Crude protein (CP) is often regarded to be the most important parameter of forage quality [37; 4]. The results showed that alfalfa + oat, alfalfa + barley, sole alfalfa forage produced higher crude protein content than their respective cereal counter parts; sole oats and sole barley, which could be the result of efficient utilization of light, atmospheric nitrogen, moisture and nutrients. Legumes tend to have higher crude protein levels than cereal crops through biological fixation of nitrogen, thus an overall improvement in crude protein is to be expected when legumes are intercropped with cereals. Crude protein improvement in legume–cereal intercropping has been reported by several studies, who reported a higher crude protein content relative to that of sole cereals [5; 38; 39].

**Table 5. Crude protein (CP) in forage yield of alfalfa, oat and barley monocultures and intercrops of alfalfa with oat and barley at different plant growth stages over a two year period**

| Cropping systems | Plant growth stages ($gkg^{-1}$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tillering (30d) | | Jointing (50d) | | Flowering (90d) | | Ripening (110d) | | CP mean | |
| | 2015 | 2016 | 2015 | ~~2016~~ | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 |
| Sole alfalfa | 12.9a | 13.5a | 15.9a | 16.8a | 23.2ab | 22.8bc | 25.7b | 25.5b | 19.4ab | 19.7ab |
| Sole oat | 6.9b | 7.5b | 10.5b | 11.4c | 21.1b | 20.1c | 23.9bc | 22.3c | 15.6c | 15.3c |
| Sole barley | 7.2b | 8.4b | 9.9b | 10.9c | 18.4c | 17.8d | 19.1c | 19.5d | 13.6d | 14.2c |
| Alfalfa + Oat | 14.3a | 13.7a | 17.4a | 17.3a | 25.7a | 27.8a | 27.1a | 29.9a | 21.1a | 22.2a |
| Alfalfa + Barley | 13.1a | 13.3a | 16.2a | 16.2a | 24.8ab | 26.1a | 26.5bc | 27.2b | 20.2a | 20.7a |
| Standard Error (±) | 1.75 | 1.58 | 1.06 | 1.77 | 0.97 | 1.25 | 0.86 | 1.15 | 1.94 | 1.52 |

d – Days after emergence. Means in the same column with different letters are significantly different ($P \leq 0.05$).

### 3.2.2 Acid Detergent Fibre (ADF)

Acid detergent fibre (ADF) recorded at different growth stages of two cropping systems; monoculture and intercropping is given in Table 6. ADF data revealed that there was significant difference among treatments for two consecutive years. In 2015, the highest ADF (32.1) was obtained from sole barley followed by sole oat (30.6) and sole alfalfa (30.2) while lowest ADF (28.6 and 27.4 respectively) was recorded with alfalfa + barley and alfalfa + oats intercropping system. In 2016, ADF values were also highest in barley, oat and alfalfa monocultures (33.5, 32.4 and 31.2 respectively) and lowest in intercrops of alfalfa with barley and oat (28.9 and 27.7 respectively). Acid detergent fibre (ADF) is important criteria for evaluating forage quality, represents the digestible energy that means as the ADF level increases, digestible energy levels decrease [36]. From the results of the study legume–

cereal intercrops have low ADF values whereas monocultures have high values. This could be partly due to efficient utilization of natural resources; light, atmospheric nitrogen, carbon dioxide, moisture and nutrients among the plants of different species legumes and cereals during different growth stages. The incorporation of legume with cereal could be of paramount importance to the low ADF of the forage mixture and subsequent soil health**.** These results are in line with the findings of other studies, who reported that combined cereal–legume forage had lower ADF concentration than sole cereal/legume [40; 10; 6].

**Table 6. Acid detergent fibre (ADF) in forage yield of alfalfa, oat and barley monocultures and intercrops of alfalfa with oat and barley at different plant growth stages over a two year period**

| Cropping systems | Plant growth stages ($gkg^{-1}$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tillering (30d) | | Jointing (50d) | | Flowering (90d) | | Ripening (110d) | | ADF mean | |
| | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 |
| Sole alfalfa | 18.1ab | 20.1b | 23.3ab | 22.1b | 37.3b | 39.4b | 42.2a | 43.2a | 30.2b | 31.2b |
| Sole oat | 19.9ab | 21.4b | 21.6b | 23.9a | 39.1a | 41.3ab | 41.9a | 42.8ab | 30.6b | 32.4ab |
| Sole barley | 21.7a | 23.1a | 25.5a | 24.6a | 38.9a | 42.8a | 42.2a | 43.5a | 32.1a | 33.5a |
| Alfalfa + Oat | 17.8b | 18.6c | 20.6b | 21.8b | 34.5c | 32.8d | 36.8b | 37.4c | 27.4c | 27.7c |
| Alfalfa + Barley | 18.5ab | 19.2c | 22.1b | 22.2b | 35.8c | 35.6c | 37.9b | 38.7c | 28.6c | 28.9c |
| Standard Error (±) | 0.58 | 0.80 | 1.46 | 0.82 | 1.55 | 1.84 | 0.76 | 1.04 | 0.92 | 1.08 |

d – Days after emergence. Means in the same column followed by different letters differ significantly at $P \leq 0.05$.

### 3.2.3 Neutral Detergent Fibre (NDF)

Neutral detergent fibre (NDF) data regarding alfalfa, oat and barley monocultures and intercrops of alfalfa with oat and barley at four growth stages are presented in Table 7. NDF recorded at different plant growth stages for two consecutive years showed significant differences among the cropping system treatments. In 2015, mean maximum NDF was recorded in sole barley (51.4) followed by sole oat (51.2), sole alfalfa (48.1) and the lowest by alfalfa + oat and alfalfa + barley (45.1 and 44.4 respectively). In 2016, maximum NDF was also noted in sole barley (51.7) followed by sole oat (50.9), sole alfalfa (48.5) and the lowest in alfalfa + oat (46.1) and alfalfa + barley (45.6) intercrops. NDF concentration is a major component of forage quality and negatively correlated with dry matter intake, which means as NDF in the forage increases, animals will consume less forage [36]. From the results, it appears that NDF values are lower in cereal legume intercrops and higher in sole cropping. The lower NDF of cereal legume intercropping was probably the efficient utilization of natural resources and minimum competition among the plants of different species during different growth stages. The results of this study are similar with previous studies, which investigated legume cereal mixtures and recorded the highest NDF in sole cropping and lowest in intercropping systems [41; 11; 2].

**Table 7. Neutral detergent fibre (NDF) in forage yield of alfalfa, oat and barley monocultures and intercrops of alfalfa with oat and barley at different plant growth stages over a two year period**

| Cropping systems | Plant growth stages ($gkg^{-1}$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tillering (30d) | | Jointing (50d) | | Flowering (90d) | | Ripening (110d) | | NDF mean | |
| | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 |
| Sole alfalfa | 35.6ab | 33.8b | 40.1ab | 39.8b | 55.2b | 57.4a | 61.5b | 62.9b | 48.1b | 48.5b |
| Sole oat | 39.1a | 37.6a | 44.8a | 45.1a | 56.8b | 57.2a | 63.9a | 63.5b | 51.2a | 50.9a |
| Sole barley | 38.7a | 37.5a | 43.4a | 44.7a | 59.1a | 58.8a | 64.2a | 65.8a | 51.4a | 51.7a |
| Alfalfa + Oat | 33.7b | 36.8ab | 39.8ab | 40.2ab | 51.5c | 50.8b | 55.4c | 56.7c | 45.1c | 46.1c |
| Alfalfa + Barley | 29.2c | 36.4ab | 40.5ab | 41.7ab | 52.8c | 49.3b | 55.2c | 55.1c | 44.4c | 45.6c |
| Standard Error (±) | 0.52 | 1.76 | 1.28 | 0.95 | 1.85 | 1.96 | 1.65 | 1.81 | 1.58 | 1.94 |

d – Days after emergence. Means in the same column with different letters are significantly different ($P \leq 0.05$).

## 3.3 Intercropping competition indices

### 3.3.1 Land Equivalent Ratio (LER)

LER's values were calculated for intercropping treatments in two growing seasons 2015 and 2016 to determine any advantage to be realized from the intercropping and presented in Table 8. All intercrops showed LER greater than one. The maximum LER values were obtained from the alfalfa + oat intercropping system followed by alfalfa + barley. With the values of LER higher than one from the results, this could infer that the intercropping provided significant yield advantage over monocrops. LER ranged from 1.05 to 1.11 in 2015 and 1.16 to 1.24 in 2016. Therefore, 5% to 11% in 2015 and 16% to 24% more land should be used in monocropping in order to obtain the same yield of intercropping, which indicated the advantage of the intercrops over monocrops in terms of the use of water, nutrients, carbon dioxide and light for plant growth. It was found that LER greater than one was primarily due to the nutrient cycling and increase in nitrogen content [42].

**Table 8. Land equivalent ratio for intercrops of alfalfa with oat and barley in two consecutive growing seasons (2015, 2016)**

| Intercropping | Land Equivalent Ratio (LER) 2015 | | | Land Equivalent Ratio (LER) 2016 | | |
|---|---|---|---|---|---|---|
| | $LER_{Legume}$ | $LER_{Cereal}$ | $LER_{Total}$ | $LER_{Legume}$ | $LER_{Cereal}$ | $LER_{Total}$ |
| Alfalfa + Oat | 0.77 | 0.34 | 1.11 | 0.85 | 0.39 | 1.24 |
| Alfalfa + Barley | 0.74 | 0.31 | 1.05 | 0.81 | 0.35 | 1.16 |

### 3.3.2 Relative Crowding Coefficient (K)

Relative crowding coefficient's values were calculated for intercropping treatments in two growing season 2015 and 2016 to determine competition experienced by legume (alfalfa) and cereals (oat or barley) when grown in a mixture and presented in Table 9. Relative crowding coefficient values were above one in 2015 and 2016 growing season for alfalfa + oat and alfalfa + barley mixtures. The K values of cereal were higher than K values of legume in intercropping system. From the results of the study, it appears that cereal forage was the dominant species probably due to the efficient utilization of environmental resources. These findings are in agreement with previous studies where there were low relative crowding coefficient's values of the legume when the cereal was more competitive than the legume [43; 44].

**Table 9. Relative crowding coefficient for intercrops of alfalfa with oat and barley in two consecutive growing seasons (2015, 2016)**

| Intercropping | Relative Crowding Coefficient (K) 2015 | | Relative Crowding Coefficient (K) 2016 | |
|---|---|---|---|---|
| | $K_{Legume}$ | $K_{Cereal}$ | $K_{Legume}$ | $K_{Cereal}$ |
| Alfalfa + Oat | 1.22 | 1.42 | 1.45 | 1.75 |
| Alfalfa + Barley | 1.29 | 1.38 | 1.55 | 1.67 |

### 3.3.3 Aggressivity ($A_c$)

Aggressivity values were calculated for intercropping treatments in two consecutive growing seasons 2015 and 2016 to determine the competitive relationship between legume and cereal in a mixture (Table 10). Aggressivity has similar trend as relative crowding coefficient. Cereal was the dominant species ($A_c$ positive) in the alfalfa + oat and alfalfa + barley mixtures in 2015 and 2016 growing season. Considering all aggressivity values cereal showed significant advantages in aggressivity over legume. Cereal aggressivity values were positive while such values for legume forage were negative. This effect is likely related to spatial resource use; light, water and nutrients which made cereals able to be dominant species as measured by the positive value of aggressivity. Similar results were recorded by other researchers, who reported that in other intercrops (pea and barley, soya bean and palisade grass) the cereal values of the above indices were greater than for legume, indicating that cereal was more competitive than legume [45; 46]. Similarly, greater competitive ability of sorghum and barley to exploit resources in association with chickpea and faba bean has been reported by other studies [47; 48].

**Table 10. Aggressivity for intercrops of alfalfa with oat and barley in two consecutive growing seasons (2015, 2016)**

| Intercropping | Aggressivity (A) 2015 | | Aggressivity (A) 2016 | |
|---|---|---|---|---|
| | $A_{Legume}$ | $A_{Cereal}$ | $A_{Legume}$ | $A_{Cereal}$ |
| Alfalfa + Oat | - 0.28 | 0.28 | - 0.41 | 0.41 |
| Alfalfa + Barley | - 0.21 | 0.21 | - 0.35 | 0.35 |

## 4. CONCLUSIONS

On the basis of results obtained in this study, intercropping of legume (alfalfa) with cereals (oat and barley) showed many benefits. Intercropping systems significantly increased plant height and forage yield compared with their respective monocrops. Legume–cereal intercrops improved forage quality in terms of crude protein yield (CP), acid detergent fibre (ADF) and neutral detergent fibre (NDF) concentrations than either forage species grown alone. Results obtained from intercropping competition indices indicated a superior advantage of legume-cereal mixtures because of better land use efficiency expressed as LER. Considering relative crowding coefficient (K) and aggressivity ($A_c$) values, cereal showed significant advantages over legume. The results of the study show that with alfalfa + oat and alfalfa + barley, it possible to produce greater forage yield and quality. Since there is little information in literature on forage competition indices regarding intercropping systems, the results from this study may start to fill this gap. If the primary interest of the farmer is forage production, oat or barley forage should be grown with alfalfa forage.

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