# Yield, nutritive value and *in-vitro* digestibility of cowpea (*Vigna unguiculata* L. Walp) varities intented for feed production, in Tigray, Ethiopia †

# [Rendimiento, valor nutritivo y digestibilidad *in vitro* de variedades de cowpea (*Vigna unguiculata* L. Walp) destinadas a la producción de alimentos, en Tigray, Etiopía]

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## SUMMARY

**Background:** Cowpea is known for its adaptability to lowland and moisture-stressed environments, but its potential for fodder production in high and mid-altitude areas, particularly in Ethiopia and Tigray, remains underexplored. **Objective.** To evaluate the agronomic performances and nutritional value of six cowpea varieties in the southeastern and eastern zones of Tigray, Ethiopia representing mid and high altitudes, respectively. **Methodology.** The experiment was laid-out in a factorial arrangement of two locations (mid and high altitudes) and six cowpea varieties (Sewunet, Black-eyed bean, Kenkety, Temesgen (standard check), Bekur and Bole) in a randomized complete block design with three replication. **Results.** Both fresh biomass (FB) and dry matter (DM) yields (ton/ha) were affected ($p<0.05$) by variety, location, and their interactions. Cowpea varieties grown at high altitude site required a significantly longer time ($p<0.05$) to reach 50% flowering (78.6 days) and maturity (110.3 days) compared to those grown at midland altitude. There were variation ($p<0.05$) in thousand-seeds weight (kg), number of seeds per pod (NSPP), and number of pods per plant (NPPP) between the two test locations. Temesgen required a longer time ($p<0.05$) to reach flowering and maturity, but it produced higher ($p<0.05$) dry matter yield (DMY) (5.8 tons/ha), number of branches per plant (NBPP), number of leaves per plant (NLPP), and plant height (PH) compared to other varieties. The interaction between variety and location had affected ($p<0.05$) the ash content, crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), and in-vitro dry matter digestibility (IVDMD). **Implications.** The study provides essential data on cowpea's potential for fodder production in previously under-researched areas, which could lead to increased adoption of cowpea as a dual-purpose crop for both grain and fodder, benefiting livestock systems. **Conclusion.** This study identified cowpea varieties, especially Temesgen that can be highly productive and nutritionally valuable in mid and high altitudes, helping to widen the feed resource base and address the shortage of quality feed in the region.

**Key word:** Agronomic performance**;** Cowpea; Nutritive value;Yield.

## RESUMEN

**Antecedentes:** El caupí es conocido por su adaptabilidad a ambientes de tierras bajas y con estrés hídrico, pero su potencial para la producción de forraje en áreas de altitud media y alta, particularmente en Etiopía y Tigray, permanece poco explorado. **Objetivo.** Evaluar el rendimiento agronómico y el valor nutricional de seis variedades de caupí en las zonas sureste y este de Tigray, Etiopía, que representan altitudes medias y altas, respectivamente. **Metodología.** El experimento se diseñó en un arreglo factorial de dos ubicaciones (altitudes

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medias y altas) y seis variedades de caupí (Sewunet, frijol de ojo negro, Kenkety, Temesgen (control estándar), Bekur y Bole) en un diseño de bloques completos al azar con tres réplicas. **Resultados.** Los rendimientos de biomasa fresca (FB) y de materia seca (MS) (ton/ha) se vieron afectados ($p<0.05$) por la variedad, la ubicación y sus interacciones. Las variedades de caupí cultivadas en sitios de gran altitud requirieron un tiempo significativamente mayor ($p<0.05$) para alcanzar el 50% de floración (78.6 días) y madurez (110.3 días) en comparación con las cultivadas a altitud media. Hubo variación ($p<0.05$) en el peso de mil semillas (kg), el número de semillas por vaina (NSPP) y el número de vainas por planta (NPPP) entre las dos ubicaciones de prueba. Temesgen requirió un mayor tiempo ($p<0.05$) para alcanzar la floración y la madurez, pero produjo un mayor ($p<0.05$) rendimiento de materia seca (DMY) (5.8 toneladas/ha), número de ramas por planta (NBPP), número de hojas por planta (NLPP) y altura de la planta (PH) en comparación con otras variedades. La interacción entre variedad y localidad afectó ($p<0.05$) el contenido de cenizas, proteína cruda (PC), fibra detergente neutro (FDN), fibra detergente ácido (FDA), lignina detergente ácido (LFA) y digestibilidad in vitro de la materia seca (DIVMS). **Implicaciones.** El estudio proporciona datos esenciales sobre el potencial del caupí para la producción de forraje en zonas poco investigadas, lo que podría impulsar una mayor adopción del caupí como cultivo de doble propósito, tanto para grano como para forraje, beneficiando así a los sistemas ganaderos. **Conclusión.** Este estudio identificó variedades de caupí, especialmente Temesgen, que pueden ser altamente productivas y nutricionalmente valiosas en altitudes medias y altas, lo que ayuda a ampliar la base de recursos forrajeros y a abordar la escasez de forrajes de calidad en la región.

**Palabras clave:** Rendimiento agronómico; Caupí; Valor nutritivo; Rendimiento.

## INTRODUCTION

Cowpea, as a member of the Fabaceae family and the Fabiodeae sub-family, is indeed a versatile and valuable crop in various regions. It thrives in low and mid-altitude areas and is commonly intercropped with cereals like sorghum and millet (Agbogidi, 2010). Its importance spans across semi-arid tropics in multiple continents, including Africa, Asia, southern Europe, and the Americas (Singh *et al*., 2003; Alemu *et al*., 2016). In Ethiopia, cowpea is widely cultivated and plays a dual role(Negash *et al*.,2013; Alemu *et al*., 2016; Alemu *et al*., 2019; Beshir *et al*., 2019; Kebede and Bekeko, 2020): its seeds serve as food for humans, while its biomass is a crucial feed resource for livestock (Yosep, 2014). Its high protein content makes it a significant component of livestock diets, enhancing their nutrition (Giami, 2005; Kristjanson *et al*., 2005). The reported dry matter yields, ranging from 10.56 to 11.9 tons per hectare (Gebreyowhans and Gebremeskel, 2014; Negasu *et al*., 2017), highlight its potential for both food and forage applications.

Previous studies have indicated that cowpea can enhance the intake and utilization of poor quality roughage (Akinlade *et al*., 2005; Gwanzura *et al*., 2012). In Ethiopia, there have been continuous efforts to address the shortage of quality forage types by producing and distributing more cowpea varieties. However, the performance of forage species, including cowpea, can vary across locations due to differences in soil types, temperature, and rainfall distribution. Testing the adaptability, forage yield potential, and nutritive value of different forage crops across various locations is crucial for identifying the best varieties for wider cultivation and utilization (Agza *et al*., 2012).

While there is existing data on cowpea in lowland areas (Etana *et al*., 2013; Gereziher *et al*., 2018; Asrat *et al*., 2021), there is a need for more information on how different varieties perform in varied altitudes, especially in terms of herbage yield and nutritional value. Studies in Tigray have evaluated phonological and growth traits of some cowpea varieties in lowland areas (Belay *et al*., 2017; Gereziher *et al*., 2018), but there is limited information on herbage yield or nutritional value in high and mid altitude areas. Cowpea grows primarily in lowland areas or under moisture stress environments, but good moisture promotes vegetative growth and results in better herbage yield and nutritive value (Peksen, 2007). Research focused on cowpea variteis adaptability and performance in these altitudes could provide valuable insights into its fodder production potential, optimizing yields, and improving nutritional quality in diverse conditions. This could benefit local farmers by enhancing livestock productivity and resilience in varying environmental conditions. Therefore, this research was conducted to evaluate the agronomic performance and fodder production of six cowpea varieties in the east and southeast of Tigray, Ethiopia.

## MATERIALS AND METHODS

### Description of the study area

The experiment was conducted during the main cropping season of 2021 at the Mekelle and Adigrat sites in Tigray, Northern Ethiopia. The Mekelle site, representing the mid-altitude, is located at the Mekelle Agricultural Research Center (MARC), situated at 13º 31' 23.778" N and 39º 30' 10.134" E, with an altitude of 1998 m above sea level. The mean annual maximum and minimum temperatures at MARC are 15 and 28 ºC, respectively, with 50.3% relative humidity. The annual rainfall ranges from 421 to 637 mm. Dominant soil types at MARC include Vertisols and Luvisols, with Fluvisols, Nitisols, and Phaeozems occurring less frequently. The soils are deep, with an aggregated structure and low bulk density, promoting plant growth (Esayas *et al*., 2005).

The second experimental site, in the Adigrat, Ganta-afeshum district of eastern Tigray, was choosen to represent high altitudes. The site is located about 897 km north of Addis Ababa, Ethiopia. The experiment was carried out at the *May edaga* village nursery, owned by the Ganta-afeshum district Bureau of Agriculture and Rural Development. The site is located at 14º 16' 34" N and 39º 28' 20" E. The experimental site is a characteristic highland, whose altitude is 2436.9 m above sea level. The average annual rainfall in the experimental area ranges from 400 to 600 mm. The mean annual maximum and minimum temperature range 10 to 25 $^{0}$C. The dominant types of soil are Clay loam and sandy. The predominant production systems in the rural areas of the experimental sites consist in a mixed crop-livestock farming. The main crops of the district are barley, maize, wheat and teff, different beans and pea (GAWOA, 2018, unpublished data).

**Experimental design and treatments**

The experiment was laid out in a randomized complete block design with three replicates (Figure 1). A factorial arrangement of treatments was employed with a combination of six cowpea varieties and two altitudes (mid and high altitudes) in main rainy season of 2021. The six cowpea varieties were Sewunet, Black-eye bean, Kenkety, Temesgen (standard check), Bekur, and Bole. The varieties were collected from Melkasa (Bekur and Bole), Pawe (Kenkety, Sewunet and Black-eyed), Alamata (Black-eyed), and Mekelle (Temesgen) Centers of Agricultural Research of Ethiopia. The varieties were selected based on the availability and adaptability. The experiment total area was 10.4 m*17 m (176.8 $m^2$) with a plot size of 2.8 m*2 m (5.6 $m^2$) and 40 cm or 20 cm spacing between rows or plants respectively; whereas the distance both between plots and replicates was of 1 m. The seed rate used in the experiment was 30 kg $ha^{-1}$ (Tesfay, 2019). Two seeds were sown together 20 cm apart with extra seedling thinning 20 days after germination, leaving one plant per station. Diammonium phosphate fertilizer was applied at 100 kg $ha^{-1}$ at sowing, and manual weeding was performed three times before flowering.

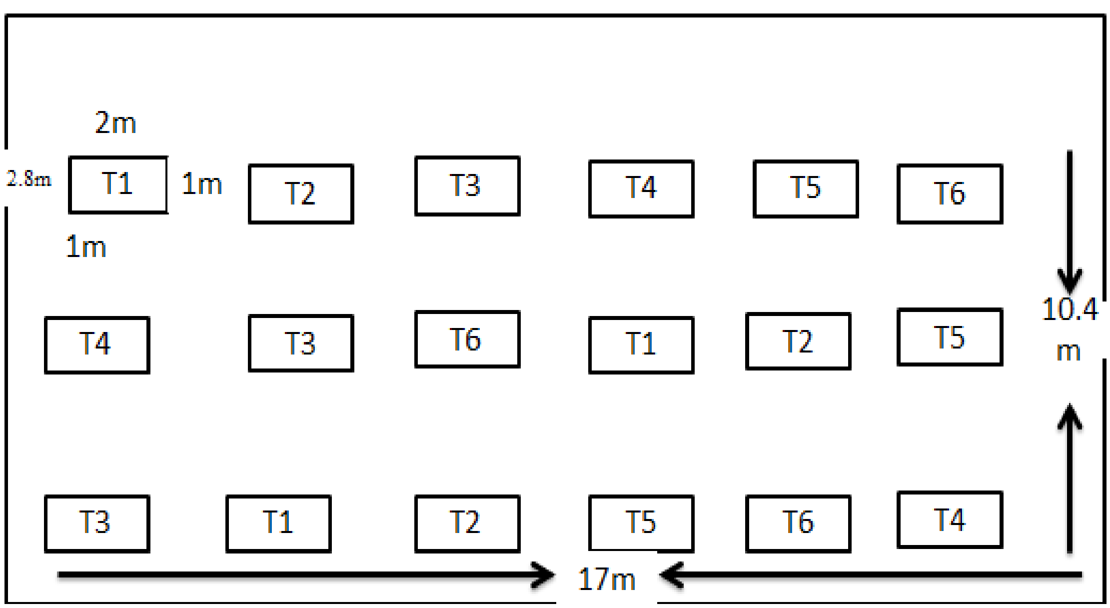


**Figure 1. Experimental layout (T= Treatment or cowpea variety, rectangles = plot size).**

**Agronomic traits and forage yield**

Relevant data was recorded throughout the experimental period. Measures were taken in the two central rows, leaving the border out to avoid border effect. The following agronomic and forage yield parameters were recorded:

- Days to Emergence: Number of days from sowing to when 90% of seeds have emerged above the ground.
- Days to 50% Flowering: Duration from sowing to when 50% of the plants in each plot show inflorescence longer than 5 cm.
- Plant Age at 50% flowering: Time from sowing to when half of the plants have reached 50% flowering.
- Days to Maturity: Number of days from planting to when the plant is fully matured.
- Hundred-Seed Weight: Weight (in grams) of 100 randomly sampled seeds.
- Days to Pod Setting: Time from planting to when the plant starts setting pods.
- Number of Seeds per Pod: Count of seeds in each pod after harvest.
- Leaf-to-Stem Ratio (LSR): Determined by harvesting all plants from two consecutive rows in the middle of each plot, separating these into stem and leaf, and calculating the ratio of leaf mass to stem mass.
- Grain Yield: Recorded in grams per plant and converted to tons per hectare.
- Harvesting Index (HI): Ratio of grain yield to above-ground dry biomass, multiplied by 100.
- Number of Pods per Plant (NBPP): Count from five arbitrarily chosen plants per plot.
- Pod Length (PL): Measured in centimeters from five randomly chosen plants per plot.
- Plant Height: Height from ground to the tip of the plant, recorded from five randomly selected plants per plot.
- Number of Branches per Plant: Total branches from the main stem of five randomly selected plants in each plot.
- Number of Leaves per Plant: Total leaves from five randomly selected plants in each plot.

To estimate herbage production, the two middle rows of each plot were measured at the pod-initiation stage. The remaining rows were used to evaluate grain yield after physiological maturity. Fresh weight of the cut plants was determined using a suspended field balance. For herbage dry matter yield, 200 g sub-samples from each genotype and replication were collected from each location, oven-dried at 65 ºC for 72 hours, or until constant weight was achieved (Tulu *et al*., 2023).

**Nutrient composition analysis**

A well-mixed composite sample from each of the three replicates of each variety was collected from each location, oven-dried, and ground through a 1 mm sieve. The samples were sent to the Animal Nutrition Laboratory of Hawassa University for chemical examination. Dry matter, ash, and crude protein contents were assessed according to AOAC (1990). Nitrogen (N) content was determined the Kjeldahl method, and crude protein was calculated as N×6.25. Neutral detergent fiber, acid detergent fiber, and acid detergent lignin were measured following Van Soest *et al*. (1991). In-vitro dry matter digestibility was assessed using the two-stage technique of Tilley and Terry (1963).

**Statistical analysis**

The General Linear Model (GLM) technique in R, version 4.2.3 (R-software, 2023), was used for statistical analyses. The least significance difference test at $p < 0.05$ was employed to compare means. For assessing herbage dry matter, crude protein, and grain yield, the effects of variety, location, and their interaction were considered as independent factors.

## RESULTS AND DISCUSSION

**Days to emergency, plant age at 50% flowering and maturity**

Results related to the length of time (days) required for cowpea varieties to emerge, reach 50% flowering, and mature are given in Table 1. The interaction between variety and location influenced ($p<0.05$) the days to maturity, with the Temesgen variety maturing later at high altitude and Kenkety maturing earlier at mid altitude. This variation emphasizes the need to select varieties based on local environmental conditions to optimize growth and yield. Varietal differences significantly impacted days to emergence, plant age at 50% flowering, maturity period, and plant height. Temesgen had longer days to 50% flowering, longer maturity period, and the tallest height compared to other varieties. In contrast, Bole and Kenkety had shorter days to emergence. The combined value for days to emerge (8.7 days) in this study is higher compared to values reported for cowpea varieties cultivated as sole crops or intercropped with maize in Chewaka District, southwest Ethiopia (Legese *et al*., 2021), and shorter than values found in a study by Agza *et al*.

(2012) under rainfed conditions in northwest lowlands of Ethiopia.

The average length of time required to reach 50% flowering for all experimental cowpea varieties in this study is comparable to the findings of Tesfay *et al*. (2018) who reported about 75.1 combined values of 50% flowering (D50F) for cowpea varieties evaluated under rainfed conditions in the lowlands of Tigray, Ethiopia. However, this result was higher than the 50% flowering of cowpea varieties reported in different parts of Ethiopia (Belay *et al*.,2017; Gereziher *et al.,*2018; Legese *et al*., 2021; Yasin *et al*., 2021; Asrat, *et al*., 2021; Goa *et al*., 2022). In another experiment, Odeseye *et al*., (2018) also reported 45-60.3 days to 50% flowering from cowpea varieties evaluated across two locations in Nigeria, which is lower than the current result. The average plant age to maturity(days) in this study is higher than the value ranged from 74 to 97.67 reported for cowpea varieties in different parts of Ethiopia (Belay *et al*., 2017; Gereziher *et al*., 2018; Legese *et al*., 2021; Yasin *et al*., 2021 and Asrat *et al*., 2021; Goa *et al*., 2022). Odeseye *et al*., (2018) also reported that the days to maturity of cowpea varieties evaluated across two locations in Nigeria varied from 64 to 78.33 days, which is lower than the current result.

The average plant height (PH) in the current study (96.31 cm) was lower than reported values from various locations in Ethiopia (58.42-90.9 cm) (Belay *et al*., 2017; Gereziher *et al*., 2018; Tesfay *et al*., 2018; Asrat *et al*., 2021; Yasin *et al*., 2021) but higher than those observed in pastoral areas of Southern Omo zone (Yoseph, 2022) and southern Ethiopia (Goa *et a*l., 2022). Bekue and Bole varieties had higher PH but required longer days to

**Table 1. Effects of variety, location and their interaction on days to emergence, days to 50% flowering, maturity and plant height for cowpea varieties.**

| Factors | | Parameters | | | |
|---|---|---|---|---|---|
| Interaction (Location *variety) | | Days to emergence | Days to 50% flowering | Days to maturity | Plant height (cm) |
| Mid altitude | Bekure | 9.66 | 68.00 | 92.66$^{gh}$ | 93.16 |
| | Black-eyed | 10.33 | 79.00 | 114.00$^{cd}$ | 104.56 |
| | Bole | 7.00 | 68.00 | 90.33$^{h}$ | 95.23 |
| | Kenkety | 7.66 | 69.00 | 86.66$^{i}$ | 98.10 |
| | Sewinet | 9.66 | 71.00 | 95.00$^{g}$ | 97.23 |
| | Temesgen | 8.66 | 82.66 | 116.66$^{bc}$ | 110.73 |
| High altitude | Bekure | 9.66 | 73.00 | 104.00$^{e}$ | 84.20 |
| | Black-eyed | 9.33 | 84.00 | 119.00$^{b}$ | 91.78 |
| | Bole | 7.33 | 75.00 | 103.00$^{ef}$ | 88.93 |
| | Kenkety | 7.33 | 75.33 | 100.33$^{f}$ | 91.50 |
| | Sewinet | 9.66 | 76.00 | 113.33$^{d}$ | 98.03 |
| | Temesgen | 8.33 | 88.00 | 126.66$^{a}$ | 102.33 |
| | MSerror | 0.44 | 1.46 | 2.93 | 13.08 |
| | P-value | 0.629 | 0.59 | <0.001 | 0.078 |
| Location | Mid altitude | 8.83 | 72.94$^{b}$ | 99.22$^{b}$ | 99.83$^{a}$ |
| | High altitude | 8.61 | 78.55$^{a}$ | 111.05$^{a}$ | 92.79$^{b}$ |
| | Mean | 8.72 | 75.75 | 105.13 | 96.31 |
| | MSerror | 0.44 | 1.46 | 2.93 | 13.08 |
| | P-value | 0.328 | <0.001 | <0.001 | <0.001 |
| Variety | Bekure | 9.66 | 70.50$^{e}$ | 98.33$^{d}$ | 88.68$^{d}$ |
| | Black-eyed | 9.83$^{a}$ | 81.50$^{b}$ | 116.50$^{b}$ | 98.17$^{b}$ |
| | Bole | 7.16$^{c}$ | 71.50$^{de}$ | 96.66$^{e}$ | 92.08$^{cd}$ |
| | Kenkety | 7.50$^{c}$ | 72.16$^{cd}$ | 93.50$^{f}$ | 94.80$^{bc}$ |
| | Sewinet | 9.66$^{a}$ | 73.50$^{c}$ | 104.16$^{c}$ | 97.63$^{b}$ |
| | Temesgen | 8.50$^{b}$ | 85.33$^{a}$ | 121.66$^{a}$ | 106.53$^{a}$ |
| | Mean | 8.72 | 75.75 | 105.13 | 96.31 |
| | MSerror | 0.44 | 1.46 | 2.93 | 13.08 |
| | P-value | <0.001 | <0.001 | <0.001 | <0.001 |

Means with different letters in the same column per variable are significantly different (p<0.05), MSerror= Mean square error

50% flowering (D50F) and maturity compared to the same varieties in Abergelle district, Tigray (Belay *et al*., 2017). Black-eyed and Bole varieties had higher PH compared to the same varieties in west Hararghe Zone (Asrat *et al*., 2021). Differences in PH might be due to high moisture leading to late maturity and the fact that varieties differ genetically in height (Peksen, 2007). Soil fertility and environmental conditions also contribute to differences in height, days to emergence, D50F, and maturity period (Kelechukwu *et al*.,2007; Srinivas *et al*., 2017; Mamaru, 2018). According to Zewdu *et al*. (2002), PH is an important parameter contributing to yield in forage crops. This suggests that varieties with higher plant height could be important for producing large quantity of forage biomass. The length of time required to emerge was not affected by test location, but D50F, days to maturity, and PH were significantly influenced by location, with mid altitude showing shorter D50F and days to maturity and higher PH compared to high altitude. This result might highlight the suitability of mid altitude for the growth and development of cowpea varieties compared to high altitude.

**Number of branches per plant, Number of pods per plant, pod length and stand vigoursity**

Table 2 presents the effects of variety, location and their interaction on the number of branches per plant (NBPP), number of pods per plant (NPPP) and pod length (PL) of cowpea differed ($p<0.05$). Temesgen variety performed well ($P<0.05$) in terms of NBPP, NPP, PL, and stand vigor at the midland location, whereas the Bekure variety showed the least performance in these parameters at the highland location. This observation can help for variety selection based on specific environmental conditions to maximize cowpea production. The mid altitude location favored ($p<0.05$) NBPP, NPPP and PL, but stand vigor did not show difference between altitudes This study indicated a higher NBPP (13.20) compared to the average reported (11.57) by Tesfay *et al*. (2018) and lower values reported by Odeseye *et al*. (2018). Ali *et al.* (2009) and Ichi *et al.* (2013) in their respective studies using different cowpea varieties observed variation in NBPP. The average NPPP (16.9) is relatively comparable to the range of 13.4-18.10 observed in other studies (Odeseye *et al*., 2018). It was observed that the NPPP for the Bole variety in their study was higher compared to the mean value (8.3) reported for the same variety in the lowland area of Tigray, Ethiopia (Gereziher *et al*., 2018). However, the NPPP in their study (13.43-18.1) was lower than the range (22.6-31.95) reported for the pastoral areas of the southern Omo zone and southern Ethiopia (Yoseph, 2022; Yasin *et al*., 2021; Goa *et al*., 2022).

The PL in their study was similar to findings from Belay *et al*. (2017) but lower than reports from southern Ethiopia and Nigeria. The current study's cowpea varieties exhibited higher vigor compared to earlier reports by Agza *et al*. (2012) and Tesfay *et al*. (2018). Variations in number of branches per plant (NBPP), number of pods per plant (NPPP), PL, and stand vigor between the current and previous studies may be attributed to differences in varieties, sowing dates, rainfall distribution, soil fertility, and other environmental factors.

**Table 2. Effect of variety, location and their interaction on NBPP, NPPP, PL and Stand Vigrousity of cowpea varieties.**

| Factors | | Parameters | | | |
|---|---|---|---|---|---|
| Interaction(Location *variety) | | NBPP | NPPP | PL | Stand Vigorousity |
| Mid altitude | Bekure | 10.20$^{g}$ | 14.80$^{f}$ | 13.94$^{e}$ | 3.33$^{cd}$ |
| | Black Eyed | 12.26$^{c}$ | 19.66$^{b}$ | 15.44$^{b}$ | 3.66$^{bcd}$ |
| | Bole | 10.66$^{f}$ | 14.06$^{gh}$ | 12.21$^{h}$ | 3.33$^{cd}$ |
| | Kenkety | 11.53$^{d}$ | 17.60$^{c}$ | 14.12$^{de}$ | 4.00$^{abc}$ |
| | Sewinet | 11.20$^{e}$ | 16.93$^{d}$ | 14.83$^{c}$ | 3.66$^{bcd}$ |
| | Temesgen | 13.20$^{a}$ | 21.73$^{a}$ | 15.84$^{a}$ | 4.66$^{a}$ |
| High altitude | Bekure | 9.46$^{i}$ | 13.73$^{h}$ | 13.17$^{g}$ | 3.00$^{d}$ |
| | Black Eyed | 10.73$^{f}$ | 14.93$^{ef}$ | 13.84$^{ef}$ | 4.00$^{abc}$ |
| | Bole | 9.93$^{h}$ | 12.80$^{i}$ | 12.03$^{h}$ | 3.33$^{cd}$ |
| | Kenkety | 11.26$^{e}$ | 15.40$^{e}$ | 14.98$^{e}$ | 3.33$^{cd}$ |
| | Sewinet | 12.46$^{b}$ | 16.46$^{d}$ | 14.37$^{d}$ | 4.33$^{ab}$ |
| | Temesgen | 10.26$^{g}$ | 14.46$^{fg}$ | 13.59$^{f}$ | 3.33$^{cd}$ |
| | MSerror | 0.10 | 0.07 | 0.03 | 0.24 |
| | P-value | <0.001 | <0.001 | <0.001 | 0.0252 |
| Location | Mid altitude | 11.51$^{a}$ | 17.46$^{a}$ | 14.39$^{a}$ | 3.77 |
| | High altitude | 10.68$^{b}$ | 14.63$^{b}$ | 13.50$^{b}$ | 3.55 |

| Factors | | Parameters | | | |
|---|---|---|---|---|---|
| Interaction(Location *variety) | | NBPP | NPPP | PL | Stand Vigorousity |
| | Mean | 11.10 | 16.05 | 13.95 | 3.66 |
| | MSerror | 0.10 | 0.07 | 0.03 | 0.24 |
| | P-value | 0.0021 | <0.001 | <0.001 | 0.1895 |
| Variety | Bekure | 9.83$^{d}$ | 14.26$^{d}$ | 13.55$^{c}$ | 3.16$^{c}$ |
| | Black Eyed | 11.50$^{b}$ | 17.30$^{b}$ | 14.64$^{a}$ | 3.83$^{ab}$ |
| | Bole | 10.30$^{c}$ | 13.43$^{e}$ | 12.12$^{d}$ | 3.33$^{bc}$ |
| | Kenkety | 11.40$^{b}$ | 16.50$^{c}$ | 14.05$^{b}$ | 3.66$^{abc}$ |
| | Sewinet | 11.83$^{a}$ | 16.70$^{c}$ | 14.60$^{a}$ | 4.00$^{a}$ |
| | Temesgen | 11.73$^{a}$ | 18.10$^{a}$ | 14.72$^{a}$ | 4.00$^{a}$ |
| | Mean | 11.10 | 16.05 | 13.95 | 3.66 |
| | MSerror | 0.10 | 0.07 | 0.03 | 0.24 |
| | P-value | 0.001 | <0.001 | <0.001 | 0.0316 |

Means with different letters in the same column per variable are significantly different (p<0.05), NBPP = number of branches per plant. NPPP = Number of pods per plant and PL = pod length (cm), MSerror= Mean square error

**Seed filling period, thousand seed weight, number of seeds per pod and grain yield**

Except for thousand seed weight (TSW), the interaction between variety and altitude affected (p<0.05) the seed filling period (SFP), number of seeds per pod (NSPP), and grain yield. Higher (P<0.05) values for NSPP and grain yield were observed at mid altitude compared to high altitude. The Temesgen variety had a later (P<0.05) SFP at high altitude, while Kenkety had an earlier SFP at mid altitude. Despite Temesgen requiring a longer SFP, it produced a higher (P<0.05) seed yield.The average SFP in the current study was higher than that reported by Belay *et al*. (2017). The Black-eyed variety had the highest (P<0.05) TSW, while Kenkety had the lowest. The average TSW (0.17) in this study was higher than the values reported by Belay *et al*. (2017) for cowpea genotypes evaluated under rainfed conditions in Abergelle district, Tigray, Ethiopia.

Among the cowpea varieties tested, Black-eyed, Sewinet, and Temesgen had higher (p<0.05) number of seeds per pod (NSPP) compared to the other varieties, while Bole had the lowest NSPP. Grain yield varied from 1.1 ton/ha (Bole) to 2.3 ton/ha (Temesgen). The average NSPP (13.3) in this study is comparable to values reported in other areas of Ethiopia (Belay *et al*., 2017; Gereziher *et al*., 2018; Yasin *et al*., 2021) and Nigeria (Odeseye *et al*., 2018) but lower than values found in the Pastoral areas of South Omo zone, southern Ethiopia. The average grain yield (1.75 ton/ha) is lower than reported averages in northern lowlands (Gebreyowhans and Gebremeskel, 2014) and southern Ethiopia (Yasin *et al*., 2021) but higher than in Abergelle district (Belay *et al*., 2017), lowlands of southern Tigray (Gereziher *et al*., 2018), and South Omo zone (Yoseph, 2022). The NSPP for the Bole variety in this study was higher compared to the average reported for the same variety in low-altitude areas of Tigray (Gereziher *et al*., 2018), but it was lower than the NSPP values reported for cowpea varieties in the Pastoral areas of South Omo zone (Yoseph, 2022). This highlights some regional variability in NSPP, which could be influenced by several factors. Discrepancies in these findings are attributed to differences in cowpea varieties, rainfall distribution, soil fertility, and other environmental factors (Iseki *et al*., 2021).

**Table 3. Effect of variety, location and their interaction on SFP (days), TSW (kg), NSPP (No) and seed yield (ton/ha) for cowpea varieties**

| Factors | | Parameters | | | |
|---|---|---|---|---|---|
| Interaction(Location *variety) | | SFP(days) | TSW(kg) | NSPP | Grain yield (ton/ha) |
| Mid altitude | Bekure | 24.66$^{f}$ | 0.14 | 13.40$^{e}$ | 1.51$^{i}$ |
| | Black-eyed | 35.00$^{b}$ | 0.27 | 14.80$^{b}$ | 2.38$^{b}$ |
| | Bole | 22.33$^{g}$ | 0.14 | 11.46$^{h}$ | 1.15$^{j}$ |
| | Kenkety | 17.66$^{h}$ | 0.14 | 13.46$^{e}$ | 1.88$^{d}$ |
| | Sewinet | 24.00$^{fg}$ | 0.16 | 14.13$^{c}$ | 1.97$^{c}$ |
| | Temesgen | 34.00$^{bc}$ | 0.17 | 15.13$^{a}$ | 2.97$^{a}$ |
| High altitude | Bekure | 31.00$^{d}$ | 0.14 | 12.60$^{g}$ | 1.51$^{i}$ |
| | Black-eyed | 35.00$^{b}$ | 0.27 | 13.26$^{ef}$ | 1.62$^{g}$ |

| Factors | | Parameters | | | |
|---|---|---|---|---|---|
| Interaction(Location *variety) | | SFP(days) | TSW(kg) | NSPP | Grain yield (ton/ha) |
| | Bole | 28.00$^{e}$ | 0.14 | 11.40$^{h}$ | 1.13$^{j}$ |
| | Kenkety | 25.00$^{f}$ | 0.13 | 13.46$^{e}$ | 1.55$^{h}$ |
| | Sewinet | 33.00$^{c}$ | 0.15 | 13.80$^{d}$ | 1.76$^{e}$ |
| | Temesgen | 38.66$^{a}$ | 0.16 | 13.06$^{f}$ | 1.67$^{f}$ |
| | MSerror | 0.98 | 5.12 | 0.03 | 0.0006 |
| | P-value | <0.001 | 0.44 | <0.001 | <0.001 |
| Location | Mid altitude | 26.27$^{b}$ | 0.173$^{a}$ | 13.73$^{a}$ | 1.96$^{a}$ |
| | High altitude | 31.77$^{a}$ | 0.172$^{b}$ | 12.93$^{b}$ | 1.54$^{b}$ |
| | Mean | 29.02 | 0.17 | 13.33 | 1.75 |
| | MSerror | 0.98 | 5.12 | 0.03 | 0.0006 |
| | P-value | <0.001 | <0.001 | <0.001 | <0.001 |
| Variety | Bekure | 27.83$^{c}$ | 0.14$^{d}$ | 13.00$^{c}$ | 1.51$^{e}$ |
| | Black-eyed | 35.00$^{b}$ | 0.27$^{a}$ | 14.03$^{a}$ | 2.00$^{b}$ |
| | Bole | 25.16$^{d}$ | 0.14$^{e}$ | 11.43$^{d}$ | 1.13$^{f}$ |
| | Kenkety | 21.33$^{e}$ | 0.13$^{f}$ | 13.46$^{b}$ | 1.72$^{d}$ |
| | Sewinet | 28.50$^{c}$ | 0.15$^{c}$ | 13.96$^{a}$ | 1.86$^{c}$ |
| | Temesgen | 36.33$^{a}$ | 0.17$^{b}$ | 14.10$^{a}$ | 2.27$^{a}$ |
| | Mean | 29.02 | 0.17 | 13.33 | 1.75 |
| | MSerror | 0.98 | 5.12 | 0.03 | 0.0006 |
| | P-value | <0.001 | <0.001 | <0.001 | <0.001 |

Means with different letters in the same column per variable are significantly different ($p<0.05$), SFP (days) = seed filling period (days), TSW (kg) = Thousand seed weight (kg) and NSPP (No) = Number of seeds per pod, MSerror= Mean square error

**Harvesting index, fresh biomass and dry matter yields**

With the exception of the harvesting index (HI), both fresh biomass yield (FBY, ton/ha) and dry matter yield (DMY, ton/ha) were impacted ($p<0.05$) by variety, location, and their interactions (Table 4). The Bekure variety exhibited the highest ($p<0.05$) HI at high altitude, while the Bole and Temesgen varieties had lower HI values at the same location. The Temesgen variety produced higher FBY and DMY at mid altitude compared to other varieties. The average HI observed in this study exceeded the HI value (0.37) reported for cowpea varieties in the Abergelle district of Tigray, Ethiopia (Belay *et al*., 2017) and southern Ethiopia (Yasin *et al*., 2021). Temesgen also outperformed other genotypes in terms of FBY and DMY, likely due to its higher values for number of branches per plant (NBPP), number of pods per plant (NPPP), pod length (PL), and plant height (PH). The average DMY in this study aligns with findings from the Gofa research station (4.2 ton/ha) (Yasin *et al*., 2021) and Gofa district (4.7 ton/ha) (Goa *et al*., 2022). However, it is lower than DMY values reported for the central rift valley of Ethiopia (5.58 ton/ha) (Etana *et al*., 2013) and the northern lowlands of Ethiopia (8.68 ton/ha) (Gebreyowhans and Gebremeskel, 2014), but higher than the DMY (2.51 ton/ha) in the Abergelle district of Tigray, Ethiopia (Belay *et al*., 2017).

**Table 4. Effect of variety, location and their interaction on SRH (%), HI, FBY (ton/ha) and DMY (ton/ha) for cowpea varieties**

| Factors | | Parameters | | |
|---|---|---|---|---|
| Interaction(Location *variety) | | HI | FBY(ton/ha) | DMY (ton/ha) |
| Mid altitude | Bekure | 0.48$^{b}$ | 14.22$^{g}$ | 3.15$^{g}$ |
| | Black-eyed | 0.39$^{ghi}$ | 28.07$^{b}$ | 6.11$^{b}$ |
| | Bole | 0.41$^{efg}$ | 13.50$^{h}$ | 2.77$^{i}$ |
| | Kenkety | 0.446$^{cb}$ | 25.12$^{cd}$ | 4.22$^{d}$ |
| | Sewinet | 0.43$^{cde}$ | 25.74$^{c}$ | 4.55$^{c}$ |
| | Temesgen | 0.40$^{fgh}$ | 31.61$^{a}$ | 7.12$^{a}$ |
| High altitude | Bekure | 0.52$^{a}$ | 12.52$^{i}$ | 2.92$^{hi}$ |
| | Black-eyed | 0.40$^{fghi}$ | 23.11$^{e}$ | 4.08$^{de}$ |
| | Bole | 0.37$^{h}$ | 13.64$^{gh}$ | 3.03$^{gh}$ |

| Factors | | Parameters | | |
|---|---|---|---|---|
| Interaction(Location *variety) | | HI | FBY(ton/ha) | DMY (ton/ha) |
| | Kenkety | 0.42$^{def}$ | 21.84$^{f}$ | 3.71$^{f}$ |
| | Sewinet | 0.45$^{bc}$ | 21.84$^{f}$ | 3.87$^{ef}$ |
| | Temesgen | 0.37$^{h}$ | 21.65$^{d}$ | 4.47$^{c}$ |
| | MSerror | 0.0003 | 0.17 | 0.016 |
| | P-value | 0.004 | <0.001 | <0.001 |
| Location | Mid altitude | 0.43 | 23.0$^{a}$ | 4.65$^{a}$ |
| | High altitude | 0.42 | 19.6$^{b}$ | 3.68$^{b}$ |
| | Mean | 0.43 | 21.32 | 4.17 |
| | MSerror | 0.0003 | 0.17 | 0.016 |
| | P-value | 0.447 | <0.001 | <0.001 |
| Variety | Bekure | 0.498$^{a}$ | 13.37$^{d}$ | 3.03$^{e}$ |
| | Black-eyed | 0,39$^{c}$ | 25.59$^{b}$ | 5.01$^{b}$ |
| | Bole | 0.39$^{c}$ | 13.57$^{d}$ | 2.90$^{e}$ |
| | Kenkety | 0.44$^{b}$ | 23.48$^{c}$ | 3.96$^{d}$ |
| | Sewinet | 0.434$^{b}$ | 25.30$^{b}$ | 4.21$^{c}$ |
| | Temesgen | 0.39$^{c}$ | 26.63$^{a}$ | 5.80$^{a}$ |
| | Mean | 0.43 | 21.32 | 4.17 |
| | MSerror | 0.0003 | 0.17 | 0.016 |
| | P-value | <0.001 | <0.001 | <0.001 |

Means with different letters in the same column per variable are significantly different (p<0.05), HI= harvesting index, FBY (ton/ha) = fresh biomass yield (ton/ha) and DMY (ton/ha) = Dry matter yield (ton/ha), MSerror= Mean square error

**Number of leaves per plant, leaf-to-stem ratio and pod setting period of cowpea varieties**

The number of leaves per plant (NLPP) and the leaf-to-stem ratio (LSR) of the cowpea varieties were influenced (p<0.05) by each factor individually as well as their interactions (Table 5). The Temesgen variety required the longest (p<0.05) pod setting period after seedling emergence at high altitude (97.66 days), while the Bekure variety had the shortest pod setting period at mid altitude (75 days). Additionally, the average NLPP was highest (P<0.05) in Temesgen at mid altitude, whereas the lowest NLPP was observed in the Bekure variety at both test locations.

The highest (p<0.05) leaf-to-stem ratio (LSR) was observed in the Temesgen variety at mid altitude, whereas the lowest LSR was recorded for the Bole variety at high altitude (1.15) (Table 5). The average pod setting period (PSP) in this study was longer compared to values reported for various cowpea varieties in the lowlands of southern Tigray, Ethiopia (28.92 days) (Gereziher *et al*., 2018) and the Chewaka district of southern Ethiopia (62.2 days) (Legese *et al*., 2021). Additionally, the LSR reported in the current study was higher than values obtained for different cowpea varieties in the northwest lowlands of Ethiopia (0.53) (Agza *et al*., 2012) and southern lowlands of Tigray, Northern Ethiopia (Tesfay *et al*., 2018). This experiment suggests that cowpea varieties performed better at mid altitude compared to high altitude, indicating that mid altitude conditions might be more suitable for cowpea cultivation. Although the Temesgen variety required more time for pod setting and maturity, it exhibited the highest NLPP. Both Temesgen and Black-eyed varieties produced higher LSR compared to the other varieties.

**Chemical composition of the cowpea varieties**

The crude protein (CP) and neutral detergent fiber (NDF) contents of cowpea varied (p<0.05) due to variety, location, and their interaction. The Temesgen and Black-eyed varieties had the highest (p<0.05) CP content (22.6%) at high altitude, while the lowest CP value was observed in Black-eyed variety at mid altitude. Cowpea varieties grown at high altitude had higher CP content compared to those grown at mid altitude. Among varieties, Temesgen had the highest CP content (20.2%), and Kenkety had the lowest (18.6%). The CP values in this study were higher than those reported for cowpea varieties in northern lowlands of Ethiopia (18.1-18.4) (Gebreyowhans and Gebremeskels, 2014) and Turkey (IIknur *et al*., 2012), but lower than values reported in the Central Rift Valley (Etana *et al*., 2013) and northwest lowlands of Ethiopia (Agza *et al*., 2012).

**Table 5. Effect of variety, location and their interaction on number of leaves per plant, leaf-to-stem ratio and pod setting period (days) for cowpea varieties.**

| Factors | | Parameters | | |
|---|---|---|---|---|
| Interaction(Location *variety) | | NLPP | LSR | PSP (days) |
| Mid altitude | Bekure | 77.5[h] | 1.28[cd] | 75.00 |
| | Black-eyed | 86.8[c] | 1.92[ab] | 89.66 |
| | Bole | 80.3[g] | 1.25[cd] | 76.00 |
| | Kenkety | 82.1[fg] | 1.36[cd] | 76.33 |
| | Sewinet | 84.7[de] | 1.75[abc] | 78.00 |
| | Temesgen | 98.5[a] | 2.17[a] | 92.00 |
| High altitude | Bekure | 77.9[h] | 1.20[cd] | 82.00 |
| | Black-eyed | 83.1[ef] | 1.62[abcd] | 94.00 |
| | Bole | 80.3[g] | 1.15[d] | 83.33 |
| | Kenkety | 86.01[cd] | 1.25[cd] | 83.66 |
| | Sewinet | 81.1[g] | 1.40[bcd] | 84.33 |
| | Temesgen | 91.3[b] | 1.65[abcd] | 97.66 |
| | MSerror | 0.10 | 0.10 | 1.44 |
| | P-value | <0.001 | 0.04 | 0.25 |
| Location | Mid altitude | 85.0[a] | 1.62[a] | 81.2[b] |
| | High altitude | 83.3[b] | 1.38[b] | 87.5[a] |
| | Mean | 84.1 | 1.50 | 84.33 |
| | MSerror | 0.10 | 0.10 | 1.44 |
| | P-value | <0.001 | 0.03 | <0.001 |
| Variety | Bekure | 77.7[e] | 1.24[b] | 78.50[e] |
| | Black-eyed | 85.0[b] | 1.77[a] | 91.83[b] |
| | Bole | 80.3[d] | 1.20[b] | 79.66[de] |
| | Kenkety | 84.1[bc] | 1.31[b] | 80.00[cd] |
| | Sewinet | 82.9[c] | 1.57[ab] | 81.16[c] |
| | Temesgen | 94.9[a] | 1.91[a] | 94.83[a] |
| | Mean | 84.1 | 1.50 | 84.33 |
| | MSerror | 0.10 | 0.10 | 1.44 |
| | P-value | 0.001 | 0.003 | <0.001 |

Means with different letters in the same column per variable are significantly different (p<0.05), NLPP=number of leaves per plant, LSR=leaf-to-steam ratio, PSP=pod setting period, MSerror= Mean square error

The ash content of cowpea differed (p<0.05) due to variety and interaction effects but did not vary by location. Black-eyed had the highest ash content (13.3%) at mid altitude, and Kenkety had the highest ash content (13.4%) at high altitude. The lowest (p<0.05) ash content was observed in Sewinet (10.9%) at mid altitude. The ash percentage in this study ranged from 11.7% (Sewinet) to 12.7% (Black-eyed), which is higher than the 9.3% to 12.1% range reported by Etana *et al*. (2013) and the lower values reported by Agza *et al*. (2012) for Sewinet (5.5%) and Black-eyed (5.7%) in North West lowlands of Ethiopia.

The NDF content ranged from 21.5% (Kenkety) to 24.5% (Bekure). The highest (p<0.05) NDF content was observed in Bekure at mid altitude (28.0%), while the lowest was in Sewinet at mid altitude (18.76%). Despite variations in NDF content among varieties and locations, all values were well below the 65% threshold that classifies feeds as low-quality Singh and Oosting (1992), indicating that the cowpea varieties in the study have a superior feeding value. The observation that cowpea varieties grown at high altitude exhibited lower NDF content (19.9%) compared to those grown at mid altitude suggests that environmental factors associated with higher altitudes might positively influence fiber quality.

The NDF ranged from 21.5% (Kenkety) to 24.5% (Bekure) (Table 6) for the varieties studied in this work. The greatest NDF was that of Bekure variety (28.0%) at mid altitude, while the lowest NDF was that of Sewinet variety (18.76%) at mid altitude. According to Singh and Oosting (1992) feeds with more than 65% NDF content are classified as low-quality feeds. However, the average NDF of cowpea varieties in both sites of the current study were far below the critical level (65%), indicating the superior feeding value of all the cowpea varieties used in this experiment. Cowpea varieties grown in high altitude site showed the lowest (19.9%) NDF content than at high altitude (Table 6).

**Table 6. Effect of variety, location and their interaction on CP, Ash and NDF for cowpea varieties.**

| Factors | | Parameters | | | |
|---|---|---|---|---|---|
| | | DM % | CP% | Ash% | NDF% |
| Location | Mid altitude | 91.2ᵃ | 17.9ᵇ | 12.2 | 25.3ᵃ |
| | High altitude | 90.9ᵇ | 20.8ᵃ | 12.3 | 19.9ᵇ |
| | Mean | 91.1 | 19.4 | 12.3 | 22.6 |
| | LSD | 0.09 | 0.03 | 0.10 | 0.16 |
| | P-value | <0.001 | <0.001 | 0.2287 | <0.001 |
| Variety | Bekure | 91.2ᵇ | 19.4ᵇ | 12.0ᶜ | 24.5ᵃ |
| | Black-eyed | 91.1ᵇ | 19.1ᵉ | 12.7ᵃ | 21.8ᶜᵈ |
| | Bole | 90.9ᶜᵈ | 19.2ᵈ | 12.5ᵃ | 22.8ᵇ |
| | Kenkety | 91.1ᵇᶜ | 18.6ᶠ | 12.3ᵇ | 21.5ᵈ |
| | Sewinet | 90.8ᵈ | 19.4ᶜ | 11.7ᵈ | 23.0ᵇ |
| | Temesgen | 91.4ᵃ | 20.2ᵃ | 12.3ᵇ | 21.9ᶜ |
| | Mean | 91.1 | 19.4 | 12.3 | 22.6 |
| | LSD | 0.16 | 0.05 | 0.17 | 0.28 |
| | P-value | <0.001 | <0.001 | <0.001 | <0.001 |
| Interaction (Location *variety) | | | | | |
| Mid altitude | Bekure | 91.4ᵃ | 18.9ᶠ | 12.1ᵈᵉ | 28.0ᵃ |
| | Black-eyed | 91.1ᶜᵈ | 15.6ᵏ | 13.3ᵃ | 24.5ᵈ |
| | Bole | 91.3ᵃᵇ | 17.2ʰ | 12.9ᵇ | 26.1ᶜ |
| | Kenkety | 90.8ᵈ | 20.9ᵈ | 11.1ᵍ | 21.5ᵉ |
| | Sewinet | 91.2ᵇᶜ | 16.8ⁱ | 10.9ᵍ | 27.3ᵇ |
| | Temesgen | 91.3ᵃᵇ | 17.7ᵍ | 12.9ᵇ | 24.2ᵈ |
| High altitude | Bekure | 90.9ᵈ | 20.3ᵉ | 11.9ᵉᶠ | 21.0ᶠ |
| | Black-eyed | 91.2ᵇᶜ | 22.6ᵃ | 12.0ᵈᵉ | 19.0ʰ |
| | Bole | 90.5ᵉ | 21.2ᶜ | 12.2ᶜᵈ | 19.5ᵍ |
| | Kenkety | 91.3ᵃᵇ | 16.4ʲ | 13.4ᵃ | 21.5ᵉ |
| | Sewinet | 90.4ᵉ | 21.9ᵇ | 12.4ᶜ | 18.8ʰ |
| | Temesgen | 91.4ᵃ | 22.6ᵃ | 11.7ᶠ | 19.5ᵍ |
| | LSD | 0.23 | 0.07 | 0.25 | 0.39 |
| | P-value | <0.001 | <0.001 | <0.001 | <0.001 |

Means with different letters in the same column per variable are significantly different (p<0.05), DM=dry matter, CP=crude protein, NDF=neutral detergent fiber, LSD= Least Significan Difference

The ADF, ADL, and IVDMD of the cowpea varieties differed significantly between varieties, locations, and their interactions (Table 7). The highest IVDMD was observed in Kenkety (84.1%) at mid altitude and Black-eyed variety at high altitude, while the lowest IVDMD was recorded in Black-eyed (77.4%) at mid altitude. This suggests that the digestibility of cowpea varieties can be influenced by both the variety and the growing conditions, which can be important for optimizing forage quality and animal nutrition.Cowpea varieties grown at high altitude yielded higher IVDMD (p<0.05) compared to those grown at mid altitude. This improvement in IVDMD might be due to higher CP and lower NDF, ADF, and ADL recorded for the same cowpea varieties at high altitude. The mean IVDMD of all the varieties ranged from 80.69% (Black-eyed) to 82.70% (Kenkety), which is higher than the 57.8% IVDMD reported by Gebreyowhans and Gebremeskel (2014) for cowpea varieties evaluated under rainfed conditions in Northern lowlands of Ethiopia. The average IVDMD for both locations surpassed the 50% digestibility threshold required for feeds to be considered acceptable (Own and Jayasuriya, 1989).

Cowpea varieties grown in mid altitude produced higher (p<0.05) ADF compared to those grown in high altitude (Table 7). Among the varieties, Bekure had the highest ADF, while Kenkety had the lowest. Feeds with lower ADF values have better nutrient availability, as ADF is negatively correlated with feed digestibility (McDonald *et al*., 2002). The differences in ADF between this study and previous works could be due to factors such as the age of cowpea varieties at harvest, the types of varieties, and environmental conditions. Forage plants with ADF below 31% are considered to have excellent quality, while those with ADF above 55% are deemed inferior (Kazemi *et al*., 2012). All the varieties evaluated in this study were classified as high quality.

**Table 7. ADF, ADL and IVDMD for the interaction variety by location for six varieties of cowpea cultivated in two locations.**

| Factors | | Parameters | | |
|---|---|---|---|---|
| | | ADF (%) | ADL (%) | IVDMD (%) |
| Location | Mid altitude | 17.5[a] | 2.7[a] | 80.0[b] |
| | High altitude | 13.5[b] | 1.8[b] | 82.8[a] |
| | Mean | 15.5 | 2.3 | 81.4 |
| | LSD | 0.13 | 0.06 | 0.14 |
| | P-value | <0.001 | <0.001 | <0.001 |
| Variety | Bekure | 16.6[a] | 2.5[b] | 81.9[b] |
| | Black-eyed | 15.0[d] | 2.2[c] | 80.7[e] |
| | Bole | 16.0[b] | 2.1[cd] | 81.1[cd] |
| | Kenkety | 14.3[e] | 1.9[e] | 82.7[a] |
| | Sewinet | 15.5[c] | 2.0[de] | 81.3[c] |
| | Temesgen | 15.5[c] | 2.7[a] | 80.9[de] |
| | Mean | 15.5 | 2.25 | 81.4 |
| | LSD | 0.22 | 0.11 | 0.24 |
| | P-value | <0.001 | <0.001 | <0.001 |
| Interaction (Location*variety) | | | | |
| Mid altitude | Bekure | 18.4[b] | 3.0[b] | 81.5[e] |
| | Black-eyed | 18.3[b] | 3.4[a] | 77.4[h] |
| | Bole | 18.8[a] | 2.9[b] | 79.1[fg] |
| | Kenkety | 13.0[f] | 1.6[f] | 84.1[a] |
| | Sewinet | 18.8[a] | 2.6[c] | 79.2[f] |
| | Temesgen | 17.9[c] | 2.7[c] | 78.9[g] |
| High altitude | Bekure | 14.8[e] | 1.9[e] | 82.3[d] |
| | Black-eyed | 11.7[h] | 0.9[i] | 84.0[a] |
| | Bole | 13.3[f] | 1.2[h] | 83.0[bc] |
| | Kenkety | 15.4[d] | 2.3[d] | 81.3[e] |
| | Sewinet | 12.2[g] | 1.4[g] | 83.3[b] |
| | Temesgen | 13.2[f] | 2.7[c] | 82.85[c] |
| | LSD | 0.32 | 0.15 | 0.35 |
| | P-value | <0.001 | <0.001 | <0.001 |

Means with different letters in the same column per variable are significantly different ($p<0.05$), ADF=acid detergent fiber, ADL=acid detergent lignin, IVDMD=*in-vitro* dry matter digestibility, LSD= Least Significan Difference

The ADL of cowpea varieties grown at mid altitude (2.7%) was significantly higher than that recorded at high altitude (1.8%). Among the varieties, Temesgen had the highest ($p<0.05$) ADL content (Table 7). The ADL contents for all six cowpea varieties in both locations were below the maximum threshold of 10%, which is known to restrict dry matter intake (Reed *et al*., 1988). The observed differences in chemical composition between locations may be attributed to factors such as variations in soil composition, climate conditions, water availability, and other environmental factors. Each location's unique environmental conditions can influence the growth and development of cowpea plants, ultimately affecting their chemical composition (Ajeigbe *et al*., 2014; Kumar *et al*., 2017). Additionally, variations in nutritional quality traits across different areas may be due to differences in cowpea genotypes and environmental conditions.

## CONCLUSIONS

The results showed that cowpea variety, location, and their interaction significantly influenced most growth, yield, and chemical composition parameters. Among the varieties, Temesgen demonstrated superior performance, requiring a longer time to flower and mature, but yielding the highest dry matter, fresh biomass, number of branches per plant, number of leaves per plant, and plant height. The Black-eyed and Kenkety varieties also exhibited notable ash and in-vitro dry matter digestibility (IVDMD), showing promise for high-quality fodder.

Varieties grown at higher altitudes took more time to reach flowering and maturity but had improved crude protein content and digestibility due to lower neutral detergent fiber (NDF) and acid detergent fiber (ADF). The study revealed that mid-altitude regions were generally more favorable for higher yields and nutritional quality, though high-altitude locations provided unique advantages in terms of digestibility.

The study identified cowpea varieties, especially Temesgen, which can be highly productive and nutritionally valuable in mid and high altitudes, helping to widen the feed resource base and address the shortage of quality feed in the region. Future research should focus on optimizing the inclusion of these varieties in livestock and human diets to further enhance their value in agricultural systems. In summary, this study provides valuable insights into the adaptability and productivity of cowpea varieties in varied altitudes, offering practical recommendations for enhancing feed resources and agricultural sustainability in Tigray, Ethiopia, and similar environments. Further research is needed to determine the optimal levels of inclusion of cowpea biomass and grains in ruminant and monogastric animal feed as well as in human diets to maximize their benefits.

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