Proximate and mineral composition of Ethiopian pea (*Pisum sativum* var. *abyssinicum* A. Braun) landraces vary across altitudinal ecosystems

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Proximate and mineral composition of Ethiopian pea (Pisum sativum var. abyssinicum A. Braun) landraces vary across altitudinal ecosystems

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Abstract: This study was aimed at determining the chemical (nutrient) composition of three Ethiopian pea landraces at three different altitudinal gradients in Ethiopia. Seeds of Sirinka 2017 (midland), Gedober 2017 (lowland) and Wemberet 2017 (highland) were collected from farmers’ fields. The Kjeldahl method was used to determine crude protein content. The carbohydrate and fat contents were evaluated by arithmetic difference and soxhlet fat extraction methods, respectively. Fiber content was analyzed by Megazyme method. To determine mineral quantities, we used ICP-OES technique. The results indicated variation in the proximate composition and mineral contents of the landraces. Gedober 2017 landrace grown at the highland altitude had higher crude protein, fat and fiber contents. Protein contents varied from 21.63% to 28.13%. The lowest fat content was recorded in Wemberet 2017 landrace (1.46%) both in the highland and lowland agroecosystems. Furthermore, all the landraces had high potassium (41.43–74.21 µg/g) and low sodium (0.93–27.65 µg/g) contents. Taken together, the variation in proximate composition and mineral contents of the landraces indicated differential adaptations to altitudinal agroecosystems showcasing necessity for preferential cropping.

Subjects: Agriculture & Environmental Sciences; Botany; Agronomy; Ecology - Environment Studies; Food Chemistry; Carbohydrates; Food Analysis; Lipids; Nutrition

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PUBLIC INTEREST STATEMENT

Ethiopian Pea (Pisum sativum var abyssinicum) is less known outside the tropical and subtropical belts of Africa. In Ethiopia, it is growing in limited parts of the country and it is less productive when compared with the common pea. On the other hand, the crop is very tasty and its cook called “Shiro” is liked by many Ethiopians. This narrowly distributed crop but very expensive due to its delicious food value needs to be studied. We have published data on the Ethnobotany (Biodiversitas (2019). https://doi.org/10.13057/biodiv/d190536), salt tolerance (Agric Res (2020). https://doi.org/10.1007/s40003-020-00459-2) and soil type requirement of the crop (Biodiversitas (2019). https://doi.org/10.13057/biodiv/d201202) before. The nutritive value and productivity of the landraces at different agroecologies (agroecosystems) were not studied. The current study is bridging this gap.
Keywords: Agroecosystem; ash; crude fiber; mineral nutrient; Gedober 2017; nutrition

1. Introduction
A significant population of the world is food insecure (FAO et al., 2019). To have sufficient food and feed roughly the world 7 billion people, agricultural production needs to increase. But, such increment is challenged by unpredictable global climatic conditions (Solberg et al., 2017). The most affected populations are those living in developing countries where technology is at its infant stage and agricultural intensification is rudimentary. Ethiopia, being a developing country, did not attain food security yet. The quantity and quality of diet in Ethiopia are very poor. This is shown in the global food security strategy country plan for Ethiopia (Feed the future, 2019). Therefore, it is necessary to avail inexpensive nutrient sources that enhance the diet quality of the nation. This could be achieved by crop selection suited to different agroecosystems. Leguminous pulse seeds could help to transform food systems and should be given priority.

Pulses have landraces that could serve as genetic resources for breeding new crop varieties to help cope with environmental and demographic changes (Esquinas-Alacazar, 2005; Smykak et al., 2015; Villa et al., 2005). Survival of plants in unfavorable conditions also requires human intervention (Ashraf & Foolad, 2007) so as to improve their productivity, including accumulation of compounds for stress mitigation (secondary metabolites). Grain legumes take up an exceptional position in world agriculture by virtue of their high protein contents and capacity to fix atmospheric nitrogen (Gebreeziabher & Tsegay, 2017; Kumar et al., 2020; Varshney et al., 2007). Regarding local legume availability, Ethiopia is among the global 34 biodiversity hotspots (Lulekal et al., 2011; Mittermeier et al., 2004) and one of the top 10 producers of total grain legumes in the world (Erena & Fatih, 2020). However, diversified pulse consumption in Ethiopia is not common. Selection for enhanced protein and mineral contents in Ethiopian pea landraces could provide improved varieties to help alleviate nutrient deficiencies. Ethiopia is endowed uniquely with a nutritive icon pulse called Ethiopian pea, which is under sporadic cultivation. The crop is rich in some amino acids such as lysine (Yeman & Skjelvåg, 2003). Unusual among legume plants, it is tolerant to different pH and soil types at low moisture (Barpete et al., 2014; Gebreslassie & Abraha, 2016). These agronomic features make Ethiopian pea a better alternative to other legumes.

Nowadays, Ethiopian pea is mainly produced for local exchange to other staple crops (in Ethiopia) due to its expensive price (Gebreeziabher & Tsegay, 2018). Growers are not consuming it commonly except when they prepare pea stew for their invited guests. Regardless of its good qualities, however, there is no information on the chemical composition of the landraces across agroecosystems where the crop grows. This study was conducted to determine the chemical composition of three Ethiopian pea landraces collected from three different altitudinal gradients and cultivated in all the three agroecosystems. Taken together, this study provides valuable information on the good performer landrace to different agroecosystems so that farmers cultivate the best performer landrace at the wanted agricultural fields.

2. Materials and methods

2.1. Description of the Ethiopian Pea (Pisum sativum var. abyssinicum) landraces and the experimental design
Seeds of three Ethiopian pea landraces (Sirinka 2017, Gedober 2017 and Wemberet 2017) were collected from farmers’ fields (Table 1). All landraces were cultivated at each study site in triplicates. The sowing time was based on local farmers sowing practice. Hundred viable seeds were sown in plots of one meter square each.

2.2. Determination of mineral concentration by inductively coupled plasma-atomic emission spectrometry (ICP-OES) analyses
Three sub-samples (5 g each) from the dried crop samples were digested in a closed microwave digestion system. Digested samples were processed for elemental analyses following the
| Landraces | Seed source district | Trial district | Trail kebelle | Agroecosystem* | Altitude* |
|-----------|----------------------|----------------|--------------|----------------|-----------|
| Sirinka 2017 | Habru (midland) | Gubalafto | Gedober | Lowland | 1379 |
| Sirinka 2017 | Habru (midland) | Habru | Sirinka | Midland | 1868 |
| Sirinka 2017 | Habru (midland) | Ofia | Wemberet | Highland | 2457 |
| Gedober 2017 | Gubalafto (lowland) | Habru | Sirinka | Midland | 1868 |
| Gedober 2017 | Gubalafto (lowland) | Gubalafto | Gedober | Lowland | 1379 |
| Gedober 2017 | Gubalafto (lowland) | Ofia | Wemberet | Highland | 2457 |
| Wemberet 2017 | Ofia (highland) | Ofia | Wemberet | Highland | 2457 |
| Wemberet 2017 | Ofia (highland) | Gubalafto | Gedober | Lowland | 1379 |
| Wemberet 2017 | Ofia (highland) | Habru | Sirinka | Midland | 1379 |

Note: the authors used the term landrace/landraces after a farm or a locality for the Ethiopian pea farmers’ seed landraces adapted to local growing conditions through natural adaptation usually with no intentional selection as per the definition reviewed by Berg (2009). Kebelles are small administrative units of a district. *Agroecosystem and altitudes (masl) are for cultivation trail districts.
procedure used by Pathak et al. (2013) for mineral composition analysis in peanut pod walls and seeds. ICP-OES technique was used to quantify calcium, potassium, sodium, magnesium, iron, manganese, copper, and zinc. Each sub-sample and the digested blank solution were read three times for each element. The triplicate samples were used to obtain average inorganic nutritious substance concentrations for each landrace in each harvest location. Finally, the level of each analyzed mineral in each digest of landrace samples was calculated for the dependence of the emission intensity on concentration for each mineral.

2.3. Estimating instrumental limit of detection (LoD) for the minerals
The mineral nutrient detection limit was performed according to Armbruster and Terry (2008). Three reagent blank solutions were digested and triplicate readings were recorded for each sample at the respective wave length (Table 2).

2.4. Elemental stock solution preparation and recovery analysis
For the analysis of samples, multi-element standard solutions were used following the procedure stated in Rüdel et al. (2007). These were prepared from single-element standards of the elements Ca, K and Na, Mg, Fe, Mn, Cu and Zn. To prepare the actual standards, the solutions were diluted before the measurement on the day they were required. To ensure the reliability of the result obtained for the analysis of the studied minerals in Ethiopian pea landrace samples, a recovery test was conducted using the formula accessed from https://www.perkinelmer.com (Table 2). Except for Na, coefficients of determination were 0.99 and above for each mineral that verified good linearity within the working range. Limit of detection was used to discriminate the presence or absence of the minerals in the samples using ICP-OES.

2.5. Proximate analysis
The moisture content was determined after desiccating 5 g fresh sample from each at 105°C for 24 h. The ash percentage was calculated by weight differences (Nielsen, 2010) with the samples incinerated at 550°C for 24 h in the oven. Since moisture was determined in the same crucible prior to ashing, the proportion of ash content for samples was calculated using the following formula (Nielsen, 2010).

\[
\text{ash content (\%) = \frac{\text{weight after ashing} - \text{tare weight of crucible}}{\text{dry sample weight} - \text{tared crucible weight}} \times 100}
\]

The Kjeldahl method with a 6.25 conversion factor was used to determine crude protein contents of the landraces. This was calculated based on the assumption that most proteins contain 16% N (100/16 = 6.25) (Nielsen, 2010). Crude fat was determined using soxhlet fat extraction method (Onwuka, 2005). Total lipids were determined according to the method of Bligh and Dyer (1959). The carbohydrate

| Minerals | Wavelength (nm) | Working standards calibration concentrations (mg/L) | Coef. of determ. (R²) | LoD (µg/L) |
|----------|-----------------|-----------------------------------------------------|-----------------------|------------|
| Ca       | 317.933         | 1.0, 2.0, 4.0, 6.0, 8.0, 10.0                        | 0.99964               | 0.05       |
| K        | 766.490         | 0.4, 0.8, 1.6, 2.4, 3.2, 4.0                         | 0.99289               | 1          |
| Na       | 589.592         | 0.2, 0.4, 0.8, 1.2, 1.6, 2.0                         | 0.95158               | 0.5        |
| Mg       | 285.213         | 0.05, 1.05, 2.05, 3.05, 4.05, 5.05                   | 0.99995               | 0.04       |
| Fe       | 238.204         | 0.05, 1.05, 2.05, 3.05, 4.05, 5.05                   | 0.99999               | 0.1        |
| Mn       | 257.610         | 0.05, 1.05, 2.05, 3.05, 4.05, 5.05                   | 0.99986               | 0.1        |
| Cu       | 327.393         | 0.05, 1.05, 2.05, 3.05, 4.05, 5.05                   | 0.99999               | 0.4        |
| Zn       | 206.200         | 0.05, 1.05, 2.05, 3.05, 4.05, 5.05                   | 0.99433               | 0.2        |

Note: the analysis is based on 3 × σ of method blanks, 5 g analytical portion, and 50 mL analytical solution.
content of the test sample was determined by estimation using the arithmetic difference method as follows: %carbohydrate = 100 − (%fat + %ash + %fiber + %protein) (Pearson, 1976). Fiber content was calculated using a method described in Megazyme (2017).

2.6. Statistical analysis
All analyses of seed chemical compositions were conducted in triplicate and results were expressed as mean ± standard deviation. The statistical analyses were done by general linear model. Analyte concentration was determined using standard curve by standardizing the instrument using the standard blank with standard solution concentration levels and by checking standard performance at the correlation coefficient (r) of linear regression (emission intensity versus concentration) of ≥0.99. An analysis of variance was performed, and means were separated using Tukey’s multiple comparison procedure with the significance level of 0.05 using SPSS 25.00 software for Windows.

3. Results and discussion
3.1. Proximate composition
Moisture contents of Ethiopian pea landraces varied from 4.22% for Sirinka 2007 landrace collected from midland and grown at the lowland agroecosystem to 6.6% of this landrace cultivated at the midland agroecosystem (Table 3). The variation might be due to the moisture content of the soil at each altitudinal range. Highlands cool slowly than lowlands thus are relatively moister. The difference in moisture contents could also possibly be due to the very nature of the landraces adapted to a wide range of growing conditions. The moisture content variations between the landraces were related to values reported by other researchers in other crops/pea varieties (Nikolopoulou et al., 2007; Wang & Daun, 2004; Winch, 2006). Winch (2006) working on different peas found that regional varieties of peas across the world were adapted to a wide range of growing conditions. Ash content increased for Wemberet 2017 landrace when cultivated in different agroecosystems compared to the others. The highest ash content (3.95%) was observed at the lowland area from Wemberet 2017 landrace (Table 3).

We found that the protein contents of the landraces varied across agroecosystems (Table 3). The highest protein contents were observed at the highland agroecosystem for the landraces Gedober 2017 and Sirinka 2017. The average protein content (26.28%) from the highland agroecosystem was higher than the other two agroecosystems. The landraces’ proteins were in accordance with the contents reported for other landraces of this species (Coyne et al., 2005; Westphal, 1974; Yemane & Skjelvåg, 2003). The wide-ranging differences in this work could be due to a combination of heritable factors within the landraces and agroecological conditions during the growing seasons. In the study on the economic value of pea protein in feed, variability in protein content was indicated as natural in cultivated peas (Crépon & Pressenda, 2005). The higher protein from highland in our study could be attributed to the landraces’ cultivation at high altitude but with relatively shorter and warmer season which could be similar to the lowland agroecosystems with short rain and high temperature. Altitude affects plant growth by influencing the meteorological conditions over the course of the growing seasons. It has been reported that short rainfall and high temperature are often responsible for raised protein content (Al-Karaki & Ereifej, 1999). This confirms the increase in the average protein level of the landraces in the highland when the moisture contents were slightly lower during the growth season compared to the other agroecosystems with a relatively higher moisture level. This probably shows that various legumes respond differently to cultivation areas or environmental changes during growth. This might not, however, portray highland peas have higher protein content compared to mid and low lands at any growing season and year.

The lowest fat concentration was recorded in Wemberet 2017 landrace (1.46%) both in the highland and lowland agroecosystems (Table 3). Sirinka 2017 cultivated in the lowland had similar value to Wemberet 2017. The highest crude fat content was obtained from Gedober 2017 landrace.
Table 3. Proximate components (g/100 g dry matter basis) of Ethiopian pea landraces cultivated at three agroecosystems

| Agroecosystem | Landraces   | Moisture* | Ash* | Protein* | Fat* | Fiber* | Carbohydrate* |
|--------------|-------------|-----------|------|----------|------|--------|---------------|
| Highland     | Sirinka 2017| 5.58 ± 0.0| 3.87 ± 0.1| 26.63 ± 0.3| 1.55 ± 0.5| 15.89 ± 0.1| 46.23 ± 0.4 |
|              | Wemberet 2017| 4.87 ± 0.0| 2.95 ± 0.0| 24.07 ± 0.2| 1.46 ± 0.5| 24.94 ± 0.3| 41.32 ± 0.2 |
|              | Gedober 2017| 5.20 ± 0.0| 3.03 ± 0.0| 28.13 ± 0.0| 1.73 ± 0.6| 26.43 ± 0.0| 43.65 ± 0.1 |
|              | Average     | 5.22 ± 0.0| 3.28 ± 0.03| 26.28 ± 0.17| 1.58 ± 0.5| 22.42 ± 0.1| 43.73 ± 0.2 |
| Midland      | Sirinka 2017| 6.6 ± 0.2 | 3.29 ± 0.0| 23.88 ± 0.1| 1.55 ± 0.4| 22.82 ± 0.0| 40.64 ± 0.2 |
|              | Wemberet 2017| 5.86 ± 0.1| 3.49 ± 0.0| 24.25 ± 0.0| 1.54 ± 0.4| 21.24 ± 0.2| 38.24 ± 0.1 |
|              | Gedober 2017| 5.31 ± 0.0| 2.93 ± 0.0| 24.19 ± 0.0| 1.80 ± 0.5| 20.23 ± 0.1| 47.10 ± 0.3 |
|              | Average     | 5.92 ± 0.1| 3.24 ± 0.0| 24.11 ± 0.03| 1.63 ± 0.3| 21.43 ± 0.1| 41.96 ± 0.2 |
| Lowland      | Sirinka 2017| 4.22 ± 0.0| 3.16 ± 0.0| 21.63 ± 0.2| 1.46 ± 0.3| 26.42 ± 0.0| 47.00 ± 0.1 |
|              | Wemberet 2017| 4.86 ± 0.0| 3.95 ± 0.2| 24.50 ± 0.0| 1.46 ± 0.3| 24.95 ± 0.2| 41.32 ± 0.5 |
|              | Gedober 2017| 6.02 ± 0.3| 2.76 ± 0.0| 24.13 ± 0.0| 1.71 ± 0.0| 23.11 ± 0.4| 45.89 ± 0.1 |
|              | Average     | 5.03 ± 0.1| 3.29 ± 0.06| 24.42 ± 0.06| 1.54 ± 0.2| 24.83 ± 0.2| 44.74 ± 0.23 |

*Values are mean ± standard deviation of triplicate determinations.
when cultivated both on the highland (1.73%) and the lowland (1.71%) areas. The same trend was observed in the study by Grela et al. (2017) where they determined fat of legume seeds and their fatty acid profiles differ considerably between the legume species and even between their varieties. Sirinka 2017 landrace was less affected by the agroecosystems and as a result had similar crude fat content both in the midland and highland areas. Overall fat and ash contents were similar to other studies for other peas (Costa et al., 2006; Erbersdobler et al., 2017; Nikolopoulou et al., 2007).

3.2. Mineral contents

All the landraces were characterized by high potassium (41.43 to 74.21 µg/g) and low content of sodium (0.93 to 27.65 µg/g) (Table 4). The highest concentration of potassium was investigated in Wemberet 2017 and Sirinka 2017 landraces (62.43 and 62.14 µg/g, respectively; P < 0.05). For the landrace Sirinka 2017 cultivated at lowland and highland agroecosystems, calcium content (96.25 and 95.53 µg/g, respectively) was observed to be highest in proportion to (even more than) potassium. From the midland agroecosystem, the greatest amount of calcium was determined for Gedober 2017 landrace (92.53 µg/g), which was a better performer on agronomic and yield traits too. The highest magnesium content was found for Gedober 2017 landraces (67.71 µg/g) grown in the lowland.

Mineral contents varied widely and were dependent on the nature of the landraces, the agroecosystem they were grown and the landraces with agroecosystem interactions. Variability trend was observed in other studies on species and varieties for Ca (Grela et al., 2017; Maganti et al., 2019) and other nutrient components (Wani & Kumar, 2014, 2015; Wani et al., 2016). Landraces cultivated by farmers and co-adapted to various biotic and abiotic stresses provide opportunities for continuous crop adaptation and selection (Sthapit et al., 2006). The role of these factors in improving field pea yields vary with agroecology and crop management practices (Khan et al., 2016).

The contents of micro minerals except for manganese and copper were observed as specific to the landraces and agroecosystems (Table 4). The greatest amount of iron was obtained in Wemberet 2017 (22.88 µg/g) that was cultivated at the lowland. On average, the landraces had highest iron content (15.22 µg/g) when cultivated at the lowland agroecosystem. The lowest average iron content (7.78 µg/g) was found in the landraces cultivated at the midland agroecosystem. Except for Wemberet 2017 landrace, all the other landraces cultivated at the lowland agroecosystem had comparatively higher zinc content (21.51 µg/g).

Wemberet 2017 landrace grown at the lowland was identified as a landrace with greater amounts of micronutrients, namely, manganese (2.14 µg/g), iron (22.88 µg/g), and copper (1.86 µg/g) compared to the other landraces and agroecosystems (altitudes).

Variations were observed in the mineral components of the evaluated Ethiopian pea landraces. The differences could be attributed to the effect of growing conditions on their phenotypes and nutrient composition of the growth media (soils). Landrace phenotypes are stated to reflect variance in growing conditions (Grossa & Miller, 2014). Also, dietary variations occur at inter and intraspecies level in crops (Hunter et al., 2019; Wani & Kumar, 2014, 2015; Wani et al., 2016).

4. Conclusion

Given the booming world population, investigation of underutilized crop landraces, thereof improved nutrition, is crucial. Pisum sativum var. abyssinicum is nutritive legume crop to Ethiopia, which is under sporadic cultivation. It has landraces growing at different agroecology. The different landraces showed varying organic and inorganic food components. Gedober 2017 landrace grown at the highland areas had better crude protein, crude fat, and crude fiber contents. Also, the same landrace grown in midland showed higher proportions of minerals Na, Ca, and Mg. For the micronutrient contents, Wemberet 2017 landrace was found to have higher proportions
## Table 4. Mineral contents of Ethiopian pea landraces (µg/g)

| Agroecosystem | Landrace      | K*           | Na*           | Ca*           | Mg*           |
|---------------|---------------|--------------|--------------|--------------|--------------|
| Highland      | Sirinka 2017  | 62.14 ± 3.46°| 27.65 ± 13.95°| 95.53 ± 4.65°| 17.05 ± 0.71°  |
|               | Wemberet 2017 | 62.43 ± 4.86°| 14.42 ± 7.38° | 12.27 ± 1.83°| 16.25 ± 1.08°  |
|               | Gedober 2017  | 41.43 ± 0.96°| 4.17 ± 4.19°  | 10.52 ± 0.08°| 39.52 ± 34.41°|
|               | Average       | 55.33 ± 3.09 | 15.41 ± 8.51  | 39.64 ± 2.19 | 24.27 ± 12.07 |
| Midland       | Sirinka 2017  | 52.83 ± 1.81°| 0.93 ± 1.02°  | 84.27 ± 2.07°| 11.46 ± 0.41°  |
|               | Wemberet 2017 | 58.04 ± 2.50°| 10.42 ± 10.68°| 62.87 ± 38.57°| 11.36 ± 0.66°  |
|               | Gedober 2017  | 43.43 ± 0.53°| 12.03 ± 13.71°| 92.53 ± 4.57°| 94.59 ± 4.47°  |
|               | Average       | 51.43 ± 4.84 | 7.79 ± 8.47   | 79.87 ± 15.07| 39.14 ± 1.85   |
| Lowland       | Sirinka 2017  | 57.49 ± 2.95°| 0.94 ± 0.15°  | 96.25 ± 3.65°| 10.78 ± 0.40°  |
|               | Wemberet 2017 | 74.21 ± 9.21°| 21.37 ± 7.20° | 15.45 ± 0.73°| 10.63 ± 0.11°  |
|               | Gedober 2017  | 43.84 ± 3.43°| 7.68 ± 10.88° | 4.11 ± 39.79°| 67.71 ± 49.89°|
|               | Average       | 58.11 ± 20   | 9.10 ± 6.08   | 38.60 ± 14.72| 29.71 ± 16.8   |
| Agroecosystem | Landrace   | Mn*       | Fe*        | Cu*        | Zn*        |
|---------------|------------|-----------|------------|------------|------------|
| Highland      | Sirinka 2017 | 1.55 ± 0.04<sup>a</sup> | 13.20 ± 0.19<sup>a</sup> | 0.95 ± 0.02<sup>a</sup> | 13.63 ± 0.04<sup>a</sup> |
|               | Wemberet 2017 | 1.72 ± 0.21<sup>a</sup> | 14.47 ± 2.36<sup>a</sup> | 1.10 ± 0.02<sup>a</sup> | 31.12 ± 25.17<sup>a</sup> |
|               | Gedober 2017  | 1.46 ± 0.30<sup>a</sup> | 5.50 ± 0.21<sup>a</sup>  | 0.86 ± 0.01<sup>a</sup> | 7.03 ± 0.01<sup>a</sup>  |
|               | Average      | 1.58 ± 0.18 | 11.06 ± 0.92 | 0.97 ± 0.02 | 17.26 ± 0.27 |
| Midland       | Sirinka 2017 | 1.38 ± 0.04<sup>a</sup> | 8.03 ± 0.55<sup>a</sup>  | 0.97 ± 0.02<sup>a</sup> | 16.45 ± 0.02<sup>a</sup> |
|               | Wemberet 2017 | 1.42 ± 0.50<sup>a</sup> | 8.39 ± 0.71<sup>a</sup>  | 1.40 ± 0.44<sup>a</sup> | 17.11 ± 1.67<sup>a</sup> |
|               | Gedober 2017  | 1.26 ± 0.05<sup>a</sup> | 6.91 ± 0.38<sup>a</sup>  | 0.98 ± 0.08<sup>a</sup> | 14.56 ± 3.48<sup>a</sup> |
|               | Average      | 1.35 ± 0.20 | 7.78 ± 0.55 | 1.12 ± 0.18 | 16.04 ± 1.72 |
| Lowland       | Sirinka 2017 | 1.43 ± 0.05<sup>a</sup> | 9.15 ± 2.06<sup>a</sup>  | 1.05 ± 0.05<sup>a</sup> | 15.48 ± 1.38<sup>a</sup> |
|               | Wemberet 2017 | 2.14 ± 1.36<sup>a</sup> | 22.88 ± 1.94<sup>a</sup> | 1.86 ± 1.33<sup>a</sup> | 28.33 ± 11.83<sup>a</sup> |
|               | Gedober 2017  | 1.85 ± 0.99<sup>a</sup> | 13.63 ± 7.13<sup>a</sup> | 1.32 ± 0.78<sup>a</sup> | 20.73 ± 10.39<sup>a</sup> |
|               | Average      | 1.81 ± 0.80 | 15.22 ± 3.71 | 1.41 ± 0.72 | 21.51 ± 7.87 |

*Values are mean ± standard deviations of triplicate determinations.

<sup>a,b,c</sup>Means down column for the landraces at each agroecosystem shown by different letters are statistically different at P < 0.05.
across all the agroecosystems with the greatest average being from the lowland grown. These results showed that farmers could selectively grow different landraces at different agroecology for a specific purpose. On average, Gedober 2017 has superior nutritive value across all studied agroecosystems.

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Berhane G Gebreegziabher was involved on project conception and design. He made the field experiments, collected and analyzed the data, and wrote first draft of the paper. Berhanu A. Tsegay participated on project conception, on development of research design, on securing finance for the project, on overall supervision of the project and on paper writing.

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