Assessment of variability in nutritional quality of wild edible fruit of *Monotheca buxifolia* (Falc.) A. DC. Along the altitudinal gradient in Pakistan

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**A B S T R A C T**

The fruit of *Monotheca buxifolia* is among the underutilized wild edible fruits that grows in Hindukush and Suleiman range mountains of Pakistan. Mountain communities consume this wild fruit as a food, medicine and it provides an important source of income. In this study, we aimed to investigate the total yield and the effect that altitude plays on its proximate composition and mineral contents as determined through phytochemical screening of this economically important wild fruit. Our results indicate a significant increase in the total fruit yield with increasing trunk diameter ($R^2 = 0.98$), height ($R^2 = 0.95$) and cover ($R^2 = 0.92$). The proximate composition shows that the crude fat and carbohydrate contents of *Monotheca* fruit significantly varies ($P < 0.05$) along the altitudinal gradient. Similarly, ANOVA followed by post hoc Tukey HSD, further confirms the variation ($P < 0.01$) in moisture contents of the fruit. Dry matter ranged from 95.28 ± 4.64 to 108 ± 3.70 g kg$^{-1}$ of the fruit’s edible portion, while protein contents varied between 17.16 % and 20.44 %. The fruits were found to be rich in minerals containing sizeable amounts of potassium, iron, phosphorus, sodium, nitrogen, magnesium, and copper. Significant difference was observed in the nitrogen ($P < 0.01$), potassium ($P < 0.05$) and sodium ($P < 0.05$) contents of the fruit along the altitudinal gradient. Similarly, tannins, flavonoids, saponins, reducing sugars, terpenoids, anthraquinones, and cardiac glycosides, were the most prominent chemicals found in *Monotheca* fruit. It was concluded that *Monotheca* fruit is a good source of carbohydrates, proteins, macro and micro-nutrients which fluctuated along the altitudinal gradient.

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1. Introduction

The northern areas of Pakistan are a hub to biodiversity due to the geography and natural conditions including high elevation (up to 8611 m), steep slopes, soil texture, temperature and precipitation (Ali et al. 2022a). These areas contribute > 42 % of the 6000 recorded vascular tree species, consisting of both cultivated (*Pinus, Eucalyptus, Populus*) and wild (*Olea, Ficus, Monotheca*) tree species (Khan et al., 2015). The edible products of wild plants are a commonly utilized source of supplementary nutrition (carbohydrates, vitamins, fats, proteins and minerals) in both developing and underdeveloped countries (Pereira et al., 2020). Approximately, two billion people across the globe are consuming wild foods for nourishment and harvesting it for an income source that improves their living conditions (Heilpern et al., 2021). Additionally, presence of different chemical compounds like organic acids, dietary fibers, phenolic compounds etc. make the wild food a source of medicines (Begum et al., 2020; Yahia et al., 2019).

For long term and sustainable utilization, conservation of the plants for non-timber forest products (NTFPs) is very critical for the livelihood of rural people (Talukdar et al., 2021). Unfortunately, there is insufficient information for most NTFPs to make scientific
decisions when it comes to justifiable harvesting and management (Masoodi et al., 2020). *Monotheca buxifolia* is an ecologically and economically important, wild fruiting tree species of family Sapotaceae native to Pakistan and Afghanistan (Abidullah et al., 2021). In Pakistan, this broadleaved tree species occupies a wide altitudinal range from 647.09 m above sea level (ASL) in the Suleiman ranges located to the west, up to 1800 m ASL in the Hindukush ranges situated to the north of the country (Ali et al., 2022b). It provides a variety of services including provisioning, cultural, regulatory and maintenance to help in the uplifting of the living conditions of local communities (Khan et al., 2020; Ali et al., 2022c).

The fruit of *Monotheca* locally called “Gurgura” is one of the important wild fruit having delicate taste, pleasant aroma, and a high nutritive value (Ali and Khan, 2022). The fruit is an income source and plays a key role in uplifting the living conditions of mountain communities, therefore, it is of the utmost importance to manage this resource in a proper way (Abidullah et al., 2021; Ehsan et al., 2020). Gurgura fruits, which ripen in mid-June, can be marketed until the end of September. The fruit starts out green, turns crimson before finally turning black as it ripens, and it has a delicious flavor. This wild fruit is rich in phenolic and flavonoid compounds and is recommended as a good base material for functional foods and nutritive supplements (Khan et al., 2020). The fruit was found to have good antibacterial, antifungal and antioxidant activities (Rehman et al., 2013).

There are many factors which affect the production, quality and storage life of fruit (Kumar and Ram, 2018). Among the environmental variables, relative elevation directly effects soil water and nutrients. Soil water is actively involved in the transmission and transport of nutrients to plants, which can significantly affect the distribution and utilization efficiency of nutrients (Hua et al., 2021). Despite the fact that the fruit is edible and often sold in rural and urban markets, no study evaluated the fruit yields and effect of altitudes on its proximate and nutritional composition. Therefore, in this study, we evaluate the total yield of *Monotheca* fruits from different sized trees based on their trunk diameter. Another important aim was to evaluate the nutritional value of *Monotheca* fruit from different altitudes by analyzing its mineral content and proximate composition. The findings of this study can lead to improved forest management, by providing a stable and high quality Gurgura industry development plan in the mountain areas.

## 2. Materials and methods

### 2.1. Production methods

Total fruit production was determined for trees of different size classes, based on trunk diameter at breast height (DBH). For this, sampled trees were classified based on DBH into three classes: (i) young trees (DBH < 40 cm), (ii) mature trees (DBH = 41 cm – 70 cm) and (iii) old trees (DBH > 70 cm). A total of 21 trees were marked at the stage of flowering for measurement (DBH = 41 cm). The marked trees were kept under regular observation to minimize both biotic (grazing, anthropogenic interference) and abiotic stresses. On maturity, fruits from all marked trees were harvested carefully and measured as suggested by Miletic et al., (2012). Mean values and standard deviation of total fruit production for each diameter class were calculated. Regression models were also developed to indicate the relationship of tree diameter (cm), height (cm) and tree cover (cm) with total yield (g).

### 2.2. Fruit sampling and processing

In Pakistan, *M. buxifolia* populations are generally distributed toward the north and west of the country at varying elevation ranges (Ali et al., 2022a). Fruits were collected and processed (Fig. 1) from trees located in different elevation zones (Table 1) ranging from 578 m to 1981 m ASL. These were than classified into 3 elevation zones: (i) Zone I was located from 499 m to 999 m ASL, (ii) Zone II was located between the range of 1000 m to 1499 m ASL, and (iii) Zone III was situated between 1500 m and 1999 m ASL (Ali et al., 2022a). A total of 21 fruit samples in replicates of 7 for each elevation zone were procured for processing. The fruits were packed in polythene bags and transported in cool boxes to the Agriculture Research Institute, in Tarnab, Peshawar (Parven et al., 2020). Before analysis, the fruits were stored at 4 °C overnight and then rinsed with distilled water (Tango et al., 2017). Seeds were separated from fruit and the pulp was homogenized and kept at 4 °C until required for analysis (Yahia et al., 2019).

### 2.3. Determination of proximate composition

Proximate composition, such as fat, crude fiber, crude protein, dry matter, and ash were determined from the homogenized pulp samples following the official methodology of the Association of Official Analytical Chemists (AOAC, 2019). Dry matter determination was made by desiccating a 2-gram sample to constant weight in an oven at a temperature of 105 °C. The dried pulp sample was then burnt in a muffle furnace at 600 °C for 6 h, cooled and weighed to determine ash weight. The macro-Kjeldahl method was used to calculate crude protein from measured nitrogen (method 2016.016, AOAC, 2019). A Soxhlet apparatus was used to estimate crude fats by using 3 g of sample and extracting with petroleum ether (40 – 60 °C). Similarly, determination of crude fiber was made by digesting 2 g of sample in 1.25 % hydrochloric acid (HCl) and sodium hydroxide (NaOH) each (method 2017.16 (45.4.18), AOAC, 2019). The whole sum of crude protein, crude fat, and crude fiber was subtracted from a 100 percent dry weight sample to compute carbohydrate levels. Calorific value (KJ) of the fruit was calculated from the percentages of crude protein, crude fat and carbohydrate (AOAC, 2019).

### 2.4. Determination of mineral composition

For the estimation of potassium (K) and sodium (Na), 0.5 g of ash from the pulp was digested in a mixture of perchloric acid (HClO₄) (60 %, 1 ml), nitric acid (HNO₃) (70 %, 5 ml) and sulfuric acid (H₂SO₄) (98 %, 0.5 ml) using low heat and swirling until the complete dissolution of the solid (Bonire et al., 1990). The digested sample were then allowed to cool normally and the volume was brought to 100 ml with distilled water. K and Na contents were then determined using flame atomic emission spectroscopy (FAES, SHIMADZU Corporation, AA 6406 series). Similarly, we also calculate the contents of calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn), copper (Cu), phosphorus (P) and manganese (Mn) following the procedure described by AOAC (method 968.08, 2019). For the estimation of Ca and Mg, a 1/10 (v/v) dilution was performed in lanthanum chloride (LaCl₃) (1.8 %, w/v) in order to avoid phosphate and ionization interference. Determination of P was made by UV-vis-NIR Spectrophotometer (UV-3101PC, SHIMADZU Corporation, Japan) following the procedure described by Lozano-Calero et al., (1996).

### 2.5. Phytochemical screening

The presence of chemical elements (tannins, saponins, anthraquinones, terpenoids, flavonoids, reducing sugars, cardiac glyco-
sides and alkaloids) in *Monotheca* fruit were checked using the standard protocols (Ayoola et al., 2008). For tannins, a 0.5 ml pulp solution was boiled followed by adding a few drops of Ferric chloride (FeCl₃) (0.1 %) and were then checked for blue-black or greenish brown coloration. Similarly, for saponins, 0.5 ml of boiled pulp solution was mixed with 5 ml distilled water and shaken vigorously until froth formation. The froth was then mixed with 3 drops of olive oil until an emulsion was formed (Olaniyi et al., 2018). Presence of anthraquinones was checked by boiling fruit pulp with H₂SO₄ followed by the addition of chloroform (CHCl₃). After removing the CHCl₃ layers, dilute NH₃ solution was added and noted for change in color. For terpenoids determination, 5 ml of extracted pulp was mixed with H₂SO₄ (2 ml) and CHCl₃ (3 ml) and noted for change in color. A mixture of 0.5 ml fruit solution with 2 ml H₂SO₄ and 5 ml NH₃ was tested for the presence of flavonoids. Likewise, 0.5 ml each of fruit pulp, Fehling A and Fehling B were mixed and heated resulting in a brick red coloration which showed the presence of reducing sugars. For cardiac glycosides, 0.5 ml of fruit pulp was mixed with 1 ml of glacial acetic acid (CH₃-COOH) followed by a drop of FeCl₃ and H₂SO₄ (1 ml) and checked for the appearance of violet or brown color rings. Alkaloids were tested by putting pulp solution on the origin of a TLC plate and mixing it with Dragendorff reagent (few drops) and observed for red coloration.

### 3. Results

#### 3.1. Fruit production

The fruit production on *M. buxifolia* trees were examined across three trunk-diameter classes and results are presented in Table 2. Small trees (DBH < 40 cm) yielded an average of 658.2 ± 32.44 g of fruit annually followed by mature (DBH = 41–70 cm) and old trees (DBH > 70 cm) with a production of 1276.4 ± 59.52 g and 3239.6 ± 77.8 g respectively. A similar pattern of increasing yields was also observed for tree height and tree cover of *M. buxifolia*.

Regression models were developed to show the relation of fruit production (g) with diameter (cm), height (cm) and cover (cm). Polynomial cubic relation explains value of R² = 0.98, 0.95 and 0.92 for diameter, cover and height respectively (Fig. 2).

#### 3.2. Proximate analysis

Proximate composition of *M. buxifolia* fruit provides valuable information about its nutritional quality. The values of dry matter, crude fat, ash, moisture, protein and carbohydrate at three different altitudinal ranges were calculated and are offered in Table 3. In contrast to dry matter, crude fats, ash and proteins, we observed a different trend for the moisture and carbohydrate con-

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**Table 1**

Global Positioning System (GPS) location of the sampling forests.

| S.no | Latitude  | Longitude | Elevation (m) | Slope (°) | S.no | Latitude  | Longitude | Elevation (m) | Slope (°) |
|------|-----------|-----------|---------------|-----------|------|-----------|-----------|---------------|-----------|
| Site 1 | 36.626 | 71.362 | 1092.7 | 23 | Site 11 | 30.999 | 69.918 | 1386.84 | 25 |
| Site 2 | 33.245 | 71.276 | 691.28 | 20 | Site 12 | 34.770 | 71.965 | 1457.85 | 32 |
| Site 3 | 31.400 | 69.806 | 1755.95 | 30 | Site 13 | 34.355 | 71.310 | 1011.93 | 32 |
| Site 4 | 34.712 | 71.810 | 1234 | 20 | Site 14 | 34.533 | 71.722 | 928.7 | 10 |
| Site 5 | 30.951 | 69.909 | 1578.86 | 35 | Site 15 | 32.796 | 69.937 | 1682.49 | 37 |
| Site 6 | 30.943 | 70.089 | 1677.31 | 32 | Site 16 | 32.389 | 69.650 | 1704.13 | 36 |
| Site 7 | 33.773 | 70.182 | 1554.78 | 37 | Site 17 | 34.589 | 71.700 | 1214.32 | 32 |
| Site 8 | 34.786 | 71.853 | 1174.09 | 20 | Site 18 | 33.366 | 70.577 | 825.7 | 20 |
| Site 9 | 34.843 | 71.985 | 1496.87 | 30 | Site 19 | 33.478 | 71.060 | 913.79 | 25 |
| Site 10 | 33.330 | 71.131 | 647.09 | 10 | Site 20 | 34.729 | 72.259 | 855.57 | 38 |

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Fig. 1. (A) *Monotheca* tree representative, (B) Collection of fruit and (C) Processing of fruit for proximate and nutritional composition.
Maximum moisture content (2.08 %) was reported at lower altitudinal zones, while it was minimum (0.85 %) at high elevation zones. Likewise, the carbohydrate contents (73.33 %) peaked at elevation Zone-I, however, the lowest value (61.11 %) was documented for the fruit of the higher elevation zone. The energy values (KJ) indicate that fruit of lower elevation zones are rich in energy (1833.76 ± 34.94 KJ) followed by high elevation zones. While *M. buxifolia* fruits of mid elevation zones were observed with the least energy content. ANOVA and post hoc Tukey HSD were performed to document significant variation in the dry matter and proximate contents of *M. buxifolia* fruit of all three elevation zones. Results of ANOVA shows no significance variation (*P* < 0.01, *P* < 0.05) in dry matter contents, ash (%) and protein contents (%) among the collected fruit samples from different elevations. However, a significant difference was observed for crude fat (*P* < 0.05), moisture content (*P* < 0.01, *P* < 0.05) and car-

### Table 2

Production of *Monotheca buxifolia* fruit from different trunk-diameter size class trees (*n* = 7).

| Sample # | Size Classes (DBH) | Diameter (cm) | Height (cm) | Cover (cm) | Production (g) |
|----------|-------------------|---------------|-------------|------------|----------------|
| 1        | >40 cm            | 33.02 ± 2.27  | 299.25 ± 16.6 | 310.04 ± 15.05 | 658.2 ± 32.44 |
| 2        | 41–70 cm          | 56.39 ± 1.48  | 418.31 ± 15.8 | 383.38 ± 10.56 | 1276.4 ± 59.52 |
| 3        | <71 cm            | 87.37 ± 4.51  | 664.16 ± 22.11 | 541.75 ± 17.1  | 3239.6 ± 77.8  |

### Table 3

Proximate composition of *Monotheca buxifolia* fruit in different altitudinal ranges from Pakistan. All parameters were based on 100 g of dry fruit weight and were in replicates of 7.

| Proximate contents | Elevation Classes (m ASL) | Zone I 500–999 m | Zone II 1000–1499 m | Zone III 1500–2000 m | F-value | P-value |
|--------------------|---------------------------|------------------|---------------------|----------------------|---------|---------|
| Dry matter (g/100 g) |                           | 97.28 ± 4.64     | 98.58 ± 4.32        | 99.15 ± 3.70         | 17.78   | 0.002** |
| Moisture (g/100 g)  |                           | 2.72 ± 0.18 a    | 1.42 ± 0.15b        | 0.85 ± 0.10b         | 18.8    | 3.8E-05** |
| Carbohydrates (g/100 g) |                       | 73.33 ± 0.40 a   | 65.53 ± 1.63 a      | 61.11 ± 2.37b        | 3.05    | 3.1E-12** |
| Crude fat (g/100 g)  |                           | 8.42 ± 0.05 a    | 9.20 ± 0.39 a       | 11.11 ± 1.05b        | 3.95    | 0.03*   |
| Ash (g/100 g)       |                           | 2.69 ± 0.29      | 3.18 ± 0.45         | 3.43 ± 0.47          | 1.14    | 0.33    |
| Crude fiber (g/100 g) |                         | 7.47 ± 0.09 a    | 7.11 ± 0.15 a       | 6.50 ± 0.22b         | 8.32    | 0.002** |
| Protein (g/100 g)   |                           | 17.16 ± 1.15     | 17.87 ± 1.15        | 20.44 ± 1.05         | 2.34    | 0.12    |
| Energy (KJ)         |                           | 1833.76 ± 34.94  | 1735.46 ± 24.53     | 1761.94 ± 43.1       | 2.10    | 0.15    |

*P* < 0.05, **P** < 0.01. Different superscript letters represent significant variations between groups.

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Fig. 2. Relationships of *Monotheca* tree diameter (cm), Height (cm) and cover (cm) with total fruit yield of *Monotheca* tree species.
bohydrous (P < 0.05). For further confirmation and recognition of difference, we performed post hoc Tukey HSD and the results are offered in Table 3. The crude fat, moisture and carbohydrate contents of higher elevation samples significantly differed from that of samples from lower and middle elevation zones.

3.3. Mineral content of the fruit

Different mineral contents including macro (N, Ca, Mg, K, P and Na) and microelements (Fe, Cu, Mn, Zn) were analyzed for all samples collected from different altitudinal ranges (Table 4). Among the macro elements, K was the most abundant mineral present in *Monotheca* fruit ranging from 38.3 ± 1.7 mg 100 g⁻¹ to 51.4 ± 4.4 mg 100 g⁻¹, followed by Na (13.7 ± 1.3 mg 100 g⁻¹ to 17.3 ± 2.4 mg 100 g⁻¹), and P (9.52 ± 0.86 mg 100 g⁻¹ to 11.3 ± 1.23 mg 100 g⁻¹). Ca and Mg were the least abundant mineral elements with values ranging from 2.77 to 2.86 mg 100 g⁻¹ and 4.98 to 5.86 ± 0.69 mg 100 g⁻¹ respectively. The amount of N content shows a decreasing pattern along the upward movement of altitudinal gradient. The highest value of 7.8 ± 0.48 mg 100 g⁻¹ was observed for lower elevation ranges while a lesser value of 5.6 ± 0.17 mg 100 g⁻¹ was recorded for the fruits collected from high altitudes i.e. 1500 to 1999 m ASL. A similar decreasing pattern was reported for K with 51.46 ± 4.41 mg 100 g⁻¹ for lower elevations and 38.32 ± 1.74 mg 100 g⁻¹ for higher elevations. Results of ANOVA and post-hoc Tukey HSD confirm a significant difference in the amount of N (P < 0.01) and K (P < 0.05) among the fruit of different altitudinal ranges.

Amongst the microelements, Fe was recorded as the most abundant mineral element in the *M. buxiifolia* fruits ranging from 28.48 ± 2.6 to 49.32 ± 1.7 mg 100 g⁻¹, followed by Mg (1.75 ± 0.28 mg 100 g⁻¹ to 1.44 ± 0.24 mg 100 g⁻¹). The rest of the microelements (Z and Cu) were recorded with a contribution of < 1 mg 100 g⁻¹. Microelements (except Fe) show no variation in the fruit samples collected from different altitudinal gradients. However, we reported a significant fluctuation (P = 1.11E-05, P < 0.01) in the Fe contents of the fruit samples of varied altitudes (Table 4). Unlike N and K, Fe content showed an increasing pattern along the altitudinal gradients. Starting from the value of 28.48 ± 2 mg 100 g⁻¹ at lower elevations this value reaches 40.99 ± 2.05 at middle elevation and 48.92 ± 1.57 mg 100 g⁻¹ for high altitudinal range.

3.4. Phytochemical screening

Phytochemical screening involved the qualitative identification of fruit constituents. This type of screening is extremely useful in identifying the class of the plant constituent and also to identify those vital phytochemicals to exploit commercially. Our results show the presence of different phytochemicals including flavonoids, terpenoids, tannins, saponins, anthraquinones and cardiac glycosides in the methanol and chloroform extracts of *Monotheca* fruit. Similarly, flavonoids, terpenoids and saponins were found in all extracts (chloroform, ethyl acetate, methanol and water) of the fruit pulp. In contrast, there were no signs of alkaloids present in any of the extracts (Table 5). Tannins and cardiac glycosides were not recorded in the water extract of fruit, and anthraquinones and cardiac glycosides were not recorded for ethyl acetate extractions.

4. Discussion

The fruit of *Monotheca* is underutilized as a food and income source across Pakistan. After ripening during June, the fruit is generally harvested by mountain communities and transported to local markets for commercial purpose (Ali et al., 2022b). Determining fruit inventories is a much more difficult task, costly and time-consuming, it is therefore more efficient and accurate to understand the factors which can influence fruit production (Snook et al., 2005). Fruit production is often estimated from tree diameter and crown volume, which is an accurate procedure for small-fruited species in comparison to large-fruited species (Venter and Witkowski, 2011). The *Monotheca* fruit is small in size with a diameter ranging from 0.85 to 1.6 cm and a mean of 1.27 cm (n = 100). Therefore, we used diameter, cover volume and height of the tree species to estimate the total yield. Linear logarithmic trends of diameter size-classes (R² = 0.98), height (R² = 0.95) and crown volume (R² = 0.92) shows strong positive correlations on total yield. The mean annual fruit production for a mature tree was estimated to be up to 4 Kg, valued at 1200 PKR. The results of the current study are similar to the findings of Venter and Witkowski, (2011) working on production of *Annona digitata* L. fruit in South Africa. Similarly, Snook et al., (2005) also reported an increase in fruit production of *Swietenia macrophylla* King, with the increase in trunk diameter of the tree.

Proximate contents of Monotheca fruit pulp consists of dry matter, carbohydrates, proteins, crude fats and crude fibers. A continuous increase in dry matter of the pulp (97.28 g to 99.15 g) leads to significant variation (P < 0.01) along the altitudinal gradient. The dry matter contents ranged between 97.28 ± 4.64 g 100 g⁻¹ and 99.15 ± 3.70 g 100 g⁻¹ which is relatively higher than those reported for *Ziziphus mauritiana* fruits (Saka et al., 2007) and *Morus* species (Imran et al., 2010). The habitat conditions of Monotheca (i.e. topographic and edaphic) are the most likely reason for this difference (Ali et al., 2022a). Carbohydrates are a rich source of

| Mineral contents | Zone I 500–999 m | Zone II 1000–1499 m | Zone III 1500–2000 m | F-value | P-value |
|------------------|-----------------|-------------------|---------------------|--------|--------|
| Nitrogen         | 7.88 ± 0.48 †   | 6.87 ± 0.44 †     | 5.65 ± 0.17²        | 9.38   | 0.0016² |
| Calcium          | 2.77 ± 0.33     | 3.04 ± 0.37       | 2.86 ± 0.48         | 0.26   | 0.79   |
| Magnesium        | 4.98 ± 0.85     | 4.59 ± 0.43       | 5.86 ± 0.69         | 1.02   | 0.33   |
| Potassium        | 51.46 ± 4.41    | 50.37 ± 4.41      | 38.32 ± 1.74³       | 4.13   | 0.03³  |
| Phosphorus       | 9.52 ± 0.86     | 9.83 ± 1.09       | 11.30 ± 1.23        | 0.31   | 0.73   |
| Sodium           | 13.73 ± 1.33    | 13.48 ± 1.09      | 17.33 ± 2.4         | 1.44   | 0.26   |
| Iron             | 28.48 ± 2.6     | 40.99 ± 2.05⁴     | 48.92 ± 1.57⁴       | 22.97  | 1.11E-05⁴ |
| Copper           | 0.30 ± 0.08     | 0.33 ± 0.06       | 0.25 ± 0.05         | 0.05   | 0.94   |
| Manganese        | 1.75 ± 0.28     | 1.86 ± 0.27       | 1.44 ± 0.24         | 0.15   | 0.85   |
| Zinc             | 0.49 ± 0.07     | 0.50 ± 0.08       | 0.49 ± 0.11         | 0.07   | 0.92   |

*P < 0.05, **P < 0.01. Different superscript letters represent significant variations between groups.*
energy and Monotheca fruits were found to be high in carbohydrate content which significantly varies \( (P < 0.01) \) with elevation. In the current study, carbohydrates ranged from 61.11 g 100 g\(^{-1}\) to 73.33 g 100 g\(^{-1}\), which is slightly lower than those reported by Begum et al. (2018). However, this value was higher than other wild and cultivated fruits such as Olive (18.4 g 100 g\(^{-1}\)), Plum (8.9 g 100 g\(^{-1}\)) etc. (Paul and Shah, 2004). A similar tendency for lower carbohydrate contents in Morus species was reported by Imran et al. (2010). Sunlight and wind also contribute significantly to the desiccation of fruit which can impact significantly the carbohydrate contents (Ruiz-Rodriguez et al., 2011). The ash contents ranged between 2.69 ± 0.29 and 3.43 ± 0.47 g 100 g\(^{-1}\) for the fruit collected from different altitudes. These values are similar to the ash contents (3.53 g 100 g\(^{-1}\)) reported in fruit pulp of Zea mays from Nigeria (Lockett et al., 2000). However, ash content values in the current study were lower than the 6.01 and 10.1 g 100 g\(^{-1}\) reported by Begum et al. (2018) and Saka and Msonthi, (1994) respectively.

Proteins are the most important component and found in the range of 17.16 to 20.44 g 100 g\(^{-1}\) in the dry fruit pulp of M. buxifolia. The current amount of protein content in wild edible fruit increases the importance of Monotheca as a nutritive supplement. These protein values are relatively higher than the 7.8 g 100 g\(^{-1}\) and 0.85 g 100 g\(^{-1}\) reported by Jan and Khan, (2016) and Begum et al., (2018) respectively. Similarly, wild fruits from Vangueria infasta, Adansonia digitata, Sclerocarya birrea, and Saccorhopospora spinosa were reported to have lower crude protein contents ranging 1.3 to 3.7 g 100 g\(^{-1}\) (Osman, 2004; Amarteifio and Mosase, 2006). Rathore, (2009), reported that fruits from Citrus X sinensis, Mangifera indica, Vitis vinifera, Musa and Carica papaya have crude protein contents of 0.7, 0.6, 0.5, 1.2 and 0.6 g 100 g\(^{-1}\), respectively.

The crude fat content in Monotheca fruit pulp significantly varies \( (P < 0.05) \) along the altitudinal gradient. Values for crude fat increase from 8.42 ± 0.05 g 100 g\(^{-1}\) for lower elevation zones to 11.11 ± 1.05 g 100 g\(^{-1}\) at higher elevation zones. These results are comparable to those reported by Begum et al., (2018). However, crude fat was comparatively less in other wild fruits like Ziziphus mauritiana (1.5 g 100 g\(^{-1}\)) which may be due to lipid degradation during drying (Nyanga et al., 2013). Crude fiber is normally considered as an indicator for non-digestible carbohydrate and lignin in the food (Akpabio and Ikpe, 2013). Amount of crude fiber reported in the current study was in the range of Masau wild fruits (7.37 ± 0.0 g 100 g\(^{-1}\)) reported by Nyanga et al., (2013). In the current study, a significant variation \( (P < 0.01) \) in the crude fiber along the altitudinal gradient was also observed. Lower elevation zones reported a high amount of crude fiber (7.47 ± 0.09 g 100 g\(^{-1}\)), while lesser quantities were observed for zones of higher elevation.

The consumption of fruit high in crude fiber helps to avoid diseases such as diabetes, cancer, coronary heart disease, obesity, high blood pressure and digestive problems (Suzana et al., 2004; Edem and Dosunmu, 2004). Although mineral elements are required in small quantity, they are believed to be very important in the formation of body structure and also in the regulation of different chemical reactions. Nutrient contents in the fruit can be significantly influenced by environmental conditions including altitudinal gradient, water availability, site condition and disturbances, etc. (Feyssa et al., 2011). In the current study, significant variation \( (P < 0.05, P < 0.01) \) in the amount of N, K and Fe content was observed. However, no variation was observed for the other elements including Ca, Mg, P, Na, Cu, Mn and Zn. In M. buxifolia fruit, potassium content was observed to be the most abundant ranging from 38.32 ± 1.74 mg 100 g\(^{-1}\) to 51.46 ± 4.41 mg 100 g\(^{-1}\). This value was lower in content than Sageretia theezans fruit (Yildirim et al., 2001), spinach (Hyun et al., 2015) and Masau wild fruits (Nyanga et al., 2013). Fruit pulp collected from lower elevation ranges were reported to be rich in potassium content in comparison to high altitudinal ranges. The role of potassium is prominent in living systems and is an important part of cell, tissue and organs (Chongtham et al., 2021). K is important for the regulation of blood pressure in humans and animals which indicates fruit pulp of M. buxifolia has the potential to control blood pressure (Haddy et al., 2006).

We found that the reported amount of macro elements (Ca, Mg, K, Na, P and N) in Gurgura fruit pulp is much lower than the range of values reported by Ndabikunze et al., (2010) for other wild fruits such as Adansonia digitata. Uapaca kirkiana. Sclerocarya birrea. Monotheca fruits normally grows in rocky soil which may be the most prominent reason for this lower amount of macro elements (Ali et al., 2022b). Microelements are very important for normal living systems and can maintain a variety of bodily functions including digestion, blood circulation, respiration, reproduction and immune system response. Similarly, microelements (Na, Fe, Cu, Mn and Zn) reported in the fruit pulp of Gurgura are also very important in cell metabolism.

Wild plants are the main source for a variety of natural products such as tannins, sterols, alkaloids, flavonoids, triterpenoids, essential oils etc. Due to their role in the maintenance of health, these natural ingredients are very important in the field of medicine (Mohamed et al., 2020). These biologically active elements are mainly found in bark, leaves, flowers, roots, fruits, and seeds etc. (Linh, 2021; Ullah et al., 2016). The current study reported the presence of some important chemicals (tannins, flavonoids, anthraquinones, cardiac glycosides, terpenoids, and saponins) in Monotheca fruit pulp. These results are consistent with the findings of Rehman et al., (2013) and Rahman et al., (2017) while working on Monotheca leaves and Monotheca stems respectively. This type of screening was helpful in recognizing the class of a plant’s constituents and to exploit such important phytochemicals commercially.

### Table 5

| Sample          | Flavonoids | Tarpenoids | Alkaloids | Tannins | Saponins | Anthraquinones | Cardiac glycosides |
|-----------------|------------|------------|-----------|---------|----------|----------------|-------------------|
| Chloroform      | +          | +          | –         | *       | *        | *              | *                 |
| Ethyl Acetate   | +          | +          | –         | *       | –        | *              | *                 |
| Methanol        | +          | +          | –         | *       | *        | *              | *                 |
| Water           | +          | +          | –         | *       | –        | *              | *                 |

5. Conclusions

Polynomial cubic regression models revealed that early-aged Monotheca trees were inferior in fruit production to older trees having trunk diameters > 71 cm DBH, heights of 664 cm and tree crowns > 541 cm. The impact of elevation on Monotheca fruit is highlighted in the amounts of dry matter, crude fibers, crude fats, moisture and carbohydrates contents. Similarly, N and K contents decreases when elevation increases, whereas a significant \( (P < 0.01) \) increase iron contents were reported with increasing altitudinal gradient. However, the impact of relative elevation on
Ca, Mg, Na, Cu, and protein contents is not obvious. The current proximate and nutritional composition along with important chemicals (terpenoids, saponins, flavonoids etc.) show that *Monotheca* fruit is an ideal food with an abundance of supplements. From the current results, it can be seen that Gurgura fruit has the potential to contribute to a balance diet in Pakistan and surrounding countries. To maintain top quality Gurgura in this region, we would suggest that irrigation must be provided as elevation increases.

**Declaration of Competing Interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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