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Biochemical composition of *Vigna* spp. genotypes

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Plants from Fabaceae Lindl. are widely distributed in the world as economically important crops due to their high content of useful nutrients. Species of the *Vigna* L. genus are used in many countries of the world because of the high content of protein in the seeds. However, no less important is to study the biochemical composition of above-ground parts of plants that can be used as fodder, medicinal or energetic. It was a study of six genotypes of *Vigna* spp. (f. 1 – *Vigna aconitifolius* Jacq., f. 2 – *V. umbellata* (Thunb.) Ohwi & H. Ohashi, f. 3 – *V. unguiculata* (L.) Walp., f. 4 – *V. unguiculata* (L.) Walp., f. 5 – *V. unguiculata* (L.) Walp., f. 6 – *V. mungo* (L.) Hepper.) to determine selected biochemical parameters. The content of dry matter for six genotypes was from 17.92 to 34.25%, total sugar content from 7.03 to 15.65%, the total content of ascorbic acid was from 62.96 (f. 2) to 115.66 (f. 1) mg%, β-carotene content for six *Vigna* genotypes was from 0.23 (f. 2) to 1.74 (f. 5) mg%, the content of tannins was 1.51–3.10%, lipids 1.78–4.22%, titrable acidity was 2.50–7.85%, content of ash in our study was from 6.58 (f. 2) to 10.75 (f. 3) %, calcium from 1.27 (f. 2) to 3.75 (f. 3) %, and phosphorus from 0.71 (f. 3) to 1.18 (f. 5) % depending on genotypes. The correlation analysis showed a very strong relations between total ash content and total calcium content ($r = 0.971$, $p \leq 0.01$), between titrable acidity and total tannin content ($r = 0.913$, $p \leq 0.01$), between carotene content and total tannin content ($r = 0.863$, $p \leq 0.01$), carotene content and titrable acidity ($r = 0.845$, $p \leq 0.01$). Thus, this study demonstrated that different genotypes of *Vigna* spp. are a good source of nutrients such as vitamins, dry matter, selected mineral components, etc. The research of the chemical composition of plants of six *Vigna* genotypes allowed to detect maximal content of dry matter for f. 2, titrable acidity, the content of tannins, β-carotene, and phosphorus for f. 5. The highest content of lipids, ash, and calcium was determined in raw f. 3. The ascorbic acid content was maximal in raw f. 1 plants.

Keywords: *Vigna*, genotype, dry matter, sugars, vitamins, macroelements

Introduction

Fabaceae Lindl. is one of the largest families known from ancient times as a food and medicinal plant group. Different representatives of Fabaceae exhibited numerous biological activities such as antioxidant, antimicrobial, antifungal, and anticancer, used for the treatment of liver disorders, hypertension, arthritis, hemorrhoids, etc. (Obistioiu et al., 2021).

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Representatives of this plant group are widespread in the different geographic areas due to various adaptive strategies and chemical evolution (Benjamim et al., 2020).

Plants of *Vigna* L. belong to the Fabaceae family, which is cultivated widely in the world and consists of more than 200 species. The main countries of *Vigna* production are Asia, Australia, subtropical Africa, etc. (Narayana and Agamuthu, 2021).

The name of this genus got from the name of the Italian botanist of the 17th century Dominico *Vigna*. More than 15 species of *Vigna* are commonly used in the world and have an important economic value due to protein content. The plant raw of *Vigna* spp. exhibited the antioxidant activity and used to treat numerous diseases: diabetes, cancer, rheumatism, etc. (Pandey, 2019).

The biochemical composition of plant raw *Vigna* spp. is glycosides, tannins, alkaloids, terpenoids, saponins, sterols, amino acids, etc. (Pandey, 2019). According to Aziagba et al. (2017), different organs of seven genotypes of *V. unguiculata* (L.) Walp. showed that minimal content of flavonoids was determined in seed extracts whereas the maximal content found depended on genotypes in the leaves, stems, or roots.

V. mungo (L.) Hepper is extensively cultivated in India and its raw is rich in flavonoids, isoflavonoids, phenolic acids, enzymes, lectins, saponins, and tocopherols. The raw of this species possess anti-inflammatory, antioxidant, and antimicrobial activity. Roots possess narcotic action and leaves demonstrated analgesic, ulcerogenic, and anti-inflammatory activities (Khan et al., 2021). As reported Solanki and Jain (2010), *V. mungo* is used in Indian traditional medicine and possesses immunomodulatory activity.

V. radiata (L.) R. Wilczek in some studies exhibited antidiabetic activity (Ayenewu, 2017). Leaf extract of *V. unguiculata* demonstrated antifungal activity against some phytopathogens that characterized them as the source of fungicide activity but it still has some diseases that fail to have maximal yield (Masangwa et al., 2013). According to Nderity et al. (2017), the antiobesity activity of methanol extracts *V. unguiculata* was determined.

V. unguiculata varieties can be recommended as fodder plants due to their chemical composition and yield of dry matter (Mohatla et al., 2016). Seeds of these plants contain 25.07–28.60% of protein, 5.13–6.22% of total lipids, 54.81–58.13% of carbohydrates, 4.25–6.84% of crude fiber, 4.97–6.72% of ash (Zia-Ul-Haq et al., 2014). However, seeds of *Vigna* spp. can be infected by *Colletotrichum destructum* O'Gara in storage that is reduced the values and content of nutrients (Amadioha and Nwazuo, 2019).

The biochemical composition of seeds of some *Vigna* species is amino acids where prevails glutamic and aspartic acids, fatty acids were to prevail in linoleic, palmitic, and oleic acids, and macroelements with high content of potassium (Zaheer et al., 2021).

The study of the genetic variation of *V. unguiculata* allowed to classify it into five cultivar-groups such biflora, melanophthalmus, sesquipedalis, textilis, and unguiculata (Pasquet, 1999).

The numerous existing reviews concerning *Vigna* spp. relate to the biochemical and nutritive composition of seeds of these species because of wide use for human food (Katoch, 2013) and fewer data about the above-ground part of these crops. This study was aimed to determine the biochemical composition of above-ground parts of raw *Vigna* genotypes in the M.M. Gryshko National Botanical Garden to evaluate the nutritional potential of these plants.

Biological material

Plant raw material was collected from a collection of Cultural Flora Department of M.M. Gryshko National Botanical Garden (NBG) of the National Academy of Sciences of Ukraine at the stage of flowering. For the biochemical analyses was used fresh raw of six genotypes of *Vigna* L. spp.: f. 1 – *Vigna aconitifolius* Jacq., f. 2 – *V. umbellata* (Thunb.) Ohwi & H. Ohashi, f. 3 – *V. unguiculata* (L.) Walp., f. 4 – *V. unguiculata* (L.) Walp., f. 5 – *V. unguiculata* (L.) Walp., f. 6 – *V. mungo* (L.) Hepper. The biochemical analysis was done at the laboratory of the Cultural Flora Department of NBG.

Biochemical analysis

Dry matter determination

Plant samples were dried in a drying oven at 105 °C till constant weight in aluminum boxes. Results are given in percentages (Hrytsajenko et al., 2003).

The total content of sugars determination

The total content of sugars was investigated by Bertrand's method in water extracts. 4 g of fresh mass was mixed and homogenized with distilled water (approximately 50 mL) in the 100 mL test-tubes and heated in the water bath at 70 °C during 15–20 min. After cooling in the obtained mixtures added 1 mL of the phosphate-oxalate mixture. After this was added

1.5 mL of lead acetate. The obtained mixture brings to the mark (100 mL) with water. After filtration from obtained solution took 50 mL and mixed with 8 mL of 20% HCl (at 70 °C in a water bath for 5 min), after cooling was neutralized by 12% NaOH and brought to the mark by distilled water (100 mL). 3 mL of obtained solution mixed with 6 mL of Fehling's solution reagent (6 min boiling in the water bath). Obtained mixture was analyzed for the total content of sugars. Results are given by percentages (Hrytsajenko et al., 2003).

The total content of ascorbic acid

Determination of ascorbic acid content conducted by method offered by K. Murri. 2 g of fresh mass mixed with 50 mL of 2% oxalic acid. Obtained mixture put into the dark for 20 min. The content of ascorbic acid in obtained extracts was determined by a 2,6-dichlorophenol-indophenol method based on the reduction properties of ascorbic acid. Obtained results are expressed in the mg% DW (Hrytsajenko et al., 2003).

The total content of carotene

The concentration of total carotene is determined according to Pleshkov (1985) using extraction with rubber solvent (petrol). 1 g of absolutely dried raw mixed with 20 mL of Kalosha petrol for 2 hours. After this obtained filtrate was measured spectrophotometrically at the wavelength 440 nm at the Unico Spectrophotometer. Obtained results expressed in mg% DW.

The total content of tannins

The content of tannins was determined with indigo carmine as an indicator (Yermakov et al., 1972). 5 g of fresh mass mixed with distilled water (approximately 50 mL) in 100 mL taste-tubes. Obtained mixture heated in the water bath at 70 °C for 2 hours. After cooling, adding water to the 100 mL, and following filtration 10 mL of filtrate was used to determine the total content of tannins. This procedure used 700 mL distilled water and 25 mL of 1% solvent of indigo carmine. Obtained results are expressed in %.

The total content of organic acids

The total content of organic acids is determined with phenolphthalein and results are calculated with a malic acid coefficient (Krishchenko, 1983). 10 mL of filtrate (the same procedure described for the determination of total content of tannins) titrated with 1 N solvent of NaOH in presence of phenolphthalein. Obtained results are expressed in percentages.

The total content of lipids

The total content of lipids is determined in the Soxhlet apparatus (Yermakov et al., 1972). The low-boiling petroleum ether (40 °C) was used as an extractor. The difference in masses before and after the extraction process is used to calculate the total lipid content.

Statistical analysis

Data were analyzed with ANOVA test and differences between means were compared through the Tukey-Kramer test ($p < 0.05$). The variability of all these parameters was evaluated using descriptive statistics.

Results and discussion

The value of Fabaceae plants as a rich source of nutrients depends on many factors such as agro-climatic conditions and genetic characteristics that also relate to *Vigna* spp. (Gonçalves et al., 2016). The biological (Tang et al., 2014) and pharmacological activities of these plants are manifested through biochemical composition (Pandey, 2019; Udeh et al., 2020).

The content of dry matter for six genotypes of *Vigna* was from 17.92 to 34.25% (Figure 1). The growth of plant organisms depends on many factors one of which is the regulatory functions of sugars. Accumulation of sugars in the plant tissues may be caused by environmental factors such as cold or drought stress, phosphorus deficiency, pathogens, and peculiarities of development such as increased sugar demand in apical meristems, buds, and seeds, etc. (Ciereszko, 2018). During gene expression, sugars translate the nutrient status in growth and developing modulation (Stephen et al., 2021). The total sugar content of investigated genotypes was from 7.03 to 15.65%. As shown in Figure 1, the maximum content of dry matter found for plants of f. 2 and minimum for plants of f. 5. The total content of sugars was highest in raw of f. 6 plants and lowest in raw of f. 4.

The content of carbohydrates of *Trifolium* spp., according to Gounden et al. (2018), was from 26.7 to 47.0% which is higher than in our samples. Another fodder crop, *Bunias orientalis* L., and its genotypes accumulated sugars from 5.07 to 8.86% which was less than in represented study (Vergun et al., 2021a). The above-ground part of legume plants of *Cicer arietinum* L. genotypes accumulated total content of sugars from 7.39 to 12.81% (Vergun et al., 2021b).

One of the most important metabolites in plant organisms is ascorbic acid which plays a significant

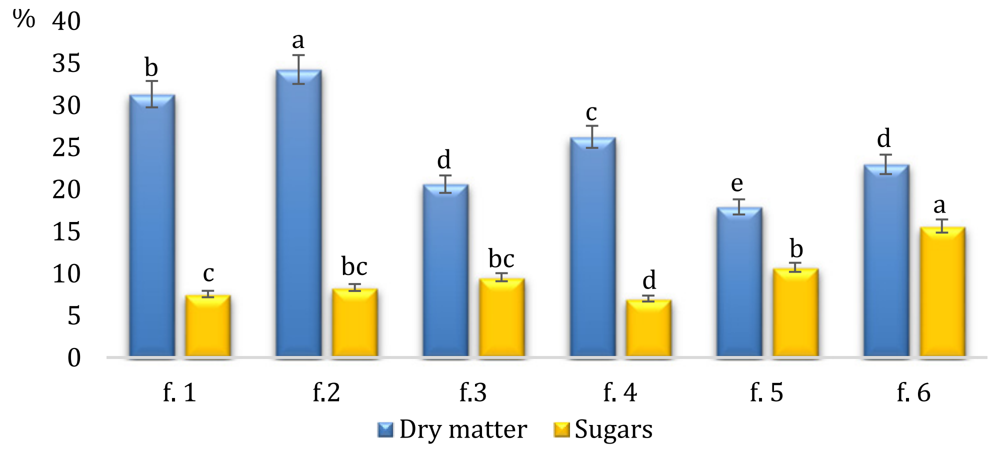

Figure 1 Content of dry matter and sugars in raw of *Vigna* spp. genotypes at the flowering stage (%)
f. 1 – *Vigna aconitifolius* Jacq.; f. 2 – *V. umbellata* (Thunb.) Ohwi & H. Ohashi; f. 3 – *V. unguiculata* (L.) Walp.; f. 4 – *V. unguiculata* (L.) Walp.; f. 5 – *V. unguiculata* (L.) Walp.; f. 6 – *V. mungo* (L.) Hepper; different superscripts in each column indicate the significant differences in the mean at p <0.05

role as an antioxidant, a cofactor for some hydroxylase enzymes, etc. (Smirnoff, 1996). The total content of ascorbic acid was from 62.96 (f. 2) to 115.66 (f. 1) mg% (Figure 2). The β-carotene content for six *Vigna* genotypes was from 0.23 (f. 2) to 1.74 (f. 5) mg%. As reported Ahenkora et al. (1998), the content of ascorbic acid in the leaves of *V. unguiculata* was 33.5–148.0 mg%. According to Wawire et al. (2011), plants of *Vigna* are a rich source of ascorbic acid, however, leaves of 1–2-months plants are prone to ascorbic acid losses. As reported Lu et al. (2019), the content of ascorbic acids in the seeds of *V. radiata* after flowering was 16.92–19.91 mg%. Comparing ascorbic acid content with other representatives of Fabaceae showed that plants from *Astragalus* L. and *Galega* L. genera accumulated 102.44–398.45 and 63.64–592.12 mg%, respectively (Vergun et al., 2012; Rakhmetov et al., 2018).

Tannins are important natural bioactive compounds, the source of which is mainly barks, leaves, seeds, and stems (Das et al., 2020). The positive and negative effect of tannins on an animal organism depends on its quantity and biological activity of it (Schofield et al., 2001). Tannins distributed in Fabaceae are mostly catechin type (Wink, 2013). In Figure 3 represented the content of tannins, lipids, and titrable acidity concentration and it was 1.51–3.10%, 1.78–4.22%, and 2.50–7.85%, respectively. Minimal titrable acidity was noticed in extracts of plants of f. 2, tannin, and lipids content in plants of f. 4. Maximal titrable acidity and tannin content was determined in plants of f. 5, and lipids in plants of f. 3.

According to Tresina et al. (2014), the content of tannins of *V. radiata* varieties was 0.50–0.59% which is 3–5 times less than in our research. The content of lipids in that study was from 3.78 to 4.34%. As reported

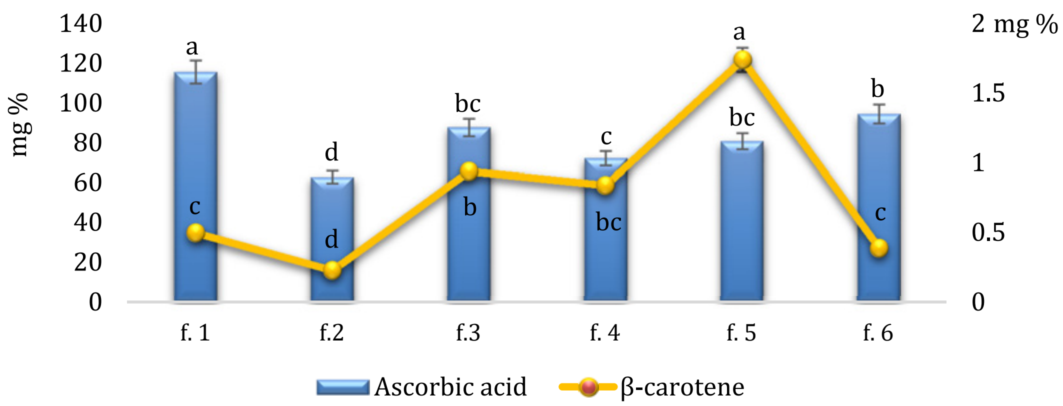

Figure 2 Content of ascorbic acid and β-carotene in raw of *Vigna* spp. genotypes at the stage of flowering (mg%)
f. 1 – *Vigna aconitifolius* Jacq.; f. 2 – *V. umbellata* (Thunb.) Ohwi & H. Ohashi; f. 3 – *V. unguiculata* (L.) Walp.; f. 4 – *V. unguiculata* (L.) Walp.; f. 5 – *V. unguiculata* (L.) Walp.; f. 6 – *V. mungo* (L.) Hepper; different superscripts in each column indicate the significant differences in the mean at p <0.05

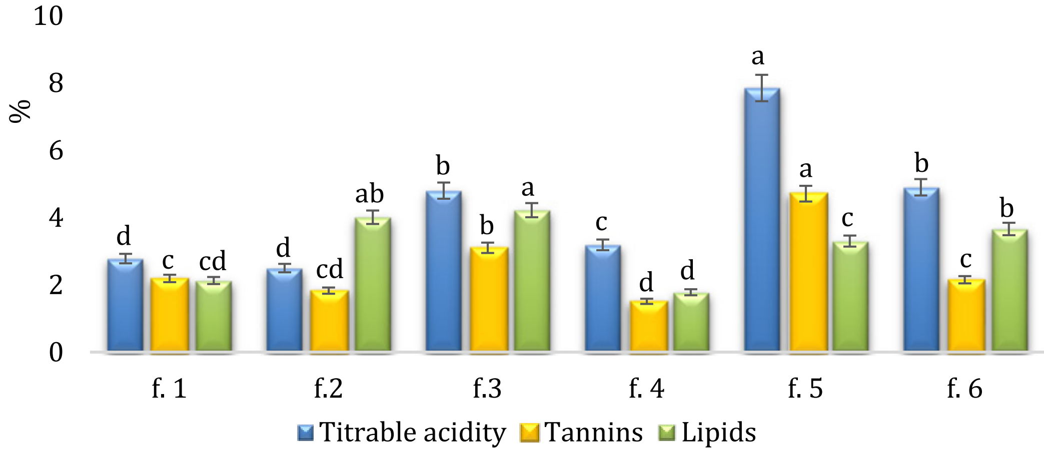

Figure 3 Content of tannins, lipids, and titrable acidity in raw *Vigna* spp. genotypes at the stage of flowering (%)
f. 1 – *Vigna aconitifolius* Jacq.; f. 2 – *V. umbellata* (Thunb.) Ohwi & H. Ohashi; f. 3 – *V. unguiculata* (L.) Walp.; f. 4 – *V. unguiculata* (L.) Walp.; f. 5 – *V. unguiculata* (L.) Walp.; f. 6 – *V. mungo* (L.) Hepper; different superscripts in each column indicate the significant differences in the mean at p <0.05

Harris et al. (2018), the main component of tannins of V. subterranea was chlorogenic acid. The content of tannins and titrable acidity in raw *Cicer arietinum* was 1.04–1.55% and 2.32–3.19%, respectively (Vergun et al., 2021b).

The mineral element accumulation in plants depends on ecological, edaphic factors and the ability of the plant to accumulate one or the other element. According to Juknevičius and Sabienė (2007), the accumulation of calcium in the legume plant was higher than in grasses. Also, calcium is an essential plant nutrient that is necessary for a plant's natural habitat with a concentration of 0.1–5%, however content of it depends on different factors (White and Broadley, 2003). Phosphorus is an equally essential element in plant life as calcium and its accumulation in plant tissues depends on the level of P in the soil (Ham et al., 2018). Phosphorus is poorly available and plays an important role in plant growth. In solubilization of phosphor participates different mechanisms including microorganisms (Gupta and Sahu, 2017).

The content of ash in our study was from 6.58 (f. 2) to 10.75 (f. 3) %, calcium from 1.27 (f. 2) to 3.75 (f. 3) %, and phosphorus from 0.71 (f. 3) to 1.18 (f. 5) % depending on genotypes. According to Tresina et al. (2014), the content of ash in *V. radiata* raw was 4.05–4.59% which is less than in our study. Udeh et al. (2020) reviewed 0.7% of ash in raw of *V. subterranean*.

Commercial *V. unguiculata* had ash content in the wet season (Nigeria) higher than in the dry season 1.32 times (Anele et al., 2011). As reported Antova et al. (2014), ash content of *V. unguiculata* was 3.2–3.7%. According to Enyiukwu et al. (2018), leaves of *V. unguiculata* contain 11.5% of ash, 5.42% of lipids, 1.61% of calcium, and 0.55% of phosphorus.

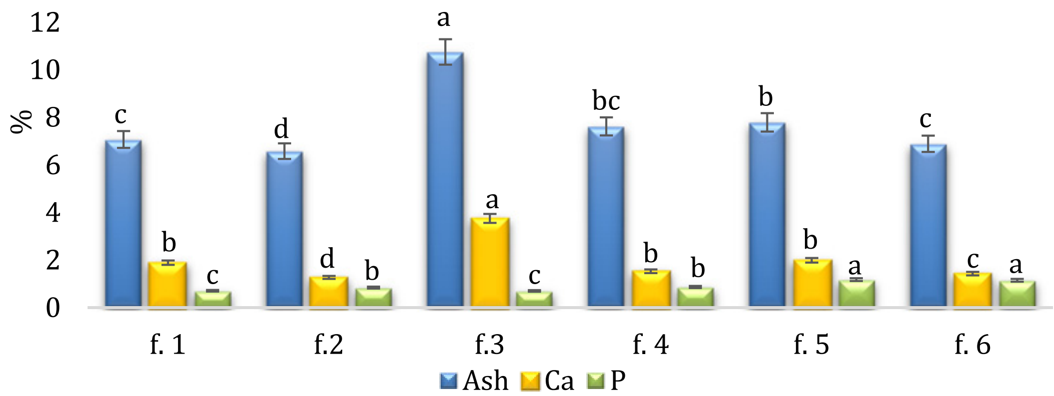

Figure 4 Content of ash, calcium, and phosphorus in raw *Vigna* spp. genotypes at the stage of flowering (%)
f. 1 – *Vigna aconitifolius* Jacq.; f. 2 – *V. umbellata* (Thunb.) Ohwi & H. Ohashi; f. 3 – *V. unguiculata* (L.) Walp.; f. 4 – *V. unguiculata* (L.) Walp.; f. 5 – *V. unguiculata* (L.) Walp.; f. 6 – *V. mungo* (L.) Hepper; different superscripts in each column indicate the significant differences in the mean at p <0.05

Table 1 Correlation between studied parameters in raw of *Vigna* spp. genotypes

Parameters	DM	TSC	AA	CC	TA	TTC	TLC	TAC	TCC
TSC	-0.486*	1							
AA	-0.052	0.172	1						
CC	-0.785**	-0.018	-0.089	1					
TA	-0.893**	0.500*	-0.030	0.845**	1				
TTC	-0.738**	0.232	0.061	0.863**	0.913**	1			
TLC	-0.222	0.483*	-0.277	-0.055	0.286	0.317	1		
TAC	-0.564	-0.088	0.045	0.406*	0.289	0.370	0.343	1	
TCC	-0.500	-0.079	0.217	0.361*	0.275	0.417*	0.373*	0.971**	1
TPC	-0.518	0.711**	-0.179	0.391*	0.700**	0.435*	0.129	-0.376	-0.433

Note: DM – dry matter content; TSC – total sugar content; AA – total ascorbic acid content; CC – total β-carotene content; TA – titrable acidity; TTC – total tannin content; TLC – total lipid content; TAC – total ash content; TCC – total calcium content; TPC – total phosphorus content; ** correlation is significant at p ≤0.01; * correlation is significant at p ≤0.05

The conducting of correlation analysis between studied biochemical parameters gives the possibility to evaluate levels depending on one other and the opposite. Pearson's coefficient is often used to describe the correlation between different biochemical parameters (Ngamdee et al., 2016). The relation of accumulation of different nutrient and non-nutrient components in raw depends on species, genotypes, conditions of growth, stage of growth, and other (Maharjan et al., 2019; Vergun et al., 2021; Yu et al., 2021). The correlation analysis showed a very strong relations between total ash content and total calcium content (r = 0.971, p ≤0.01), between titrable acidity and total tannin content (r = 0.913, p ≤0.01), between carotene content and total tannin content (r = 0.863, p ≤0.01), carotene content and titrable acidity (r = 0.845, p ≤0.01) (Table 1). A strong correlation was found between titrable acidity and total phosphorus content (r = 0.700, p ≤0.01). A very strong negative correlation was determined between dry matter content and titrable acidity (r = -0.893) of investigated raw. Strong negative relations were found between dry matter content and carotene content (r = -0.785), dry matter content, and total tannin content (r = -0.738).

According to Mohatla et al. (2016), dry matter yield of *V. unguiculata* varieties positively correlated with crude protein content (r = 0.85) and a negative correlation was found between protein content and tannins (r = -0.99).

Conclusion

Thus, this study demonstrated that different genotypes of *Vigna* spp. are a good source of nutrients such as vitamins, dry matter, selected mineral components, etc. The research of the chemical composition of plants of six *Vigna* genotypes allowed to detect maximal content of dry matter for f. 2, titrable acidity, the content of tannins, β-carotene, and phosphorus for f. 5. The highest content of lipids, ash, and calcium was determined in raw f. 3. The ascorbic acid content was maximal in raw f. 1 plants. Considering the wide use of seed raw plants of the *Vigna* genus, the results of this study about the biochemical composition of above-ground parts of these plants could be used in further biochemical and pharmacological studies as potential forage, energetic, and medicine plants.

Conflicts of interest

The authors declare no conflict of interest.

Ethical statement

This article does not contain any studies that would require an ethical statement.

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