

## Characterizing agronomic, morphological, nutritional, and phytochemical traits of local sorghum (*Sorghum bicolor* L.) plants in Indonesia

### Karakteristik agronomi, morfologi, nutrisi, dan fitokimia tanaman sorgum (*Sorghum bicolor* L.) lokal di Indonesia

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##### ABSTRACT

South Sulawesi has been designated by the Ministry of Agriculture, Indonesia, as a key sorghum-producing province. The known sorghum varieties from South Sulawesi include Batara Tojeng Eja, Batara Tojeng Bae, and local sorghum from Jeneponto. In Bulukumba Regency, South Sulawesi Province, Indonesia, local farmers traditionally cultivate local sorghum alongside maize. This study aims to gather information on the agronomic traits, morphological characteristics, nutritional composition, and phytochemical content of local sorghum from Tritiro village, Bulukumba Regency. Agronomic and morphological traits were analyzed through observations of growth and phenotypic features of the leaves, stems, roots, panicles, and seeds of sorghum. Nutritional composition was measured quantitatively, while phytochemical screening was conducted both qualitatively and quantitatively. The results show that local Tritiro sorghum has medium plant height, small stem diameter, medium panicle length, loose panicle shape, and brown seeds. Nutritional analysis revealed that local Tritiro sorghum contains 10.11% protein, 0.19% fat, 86.73% carbohydrates, 68.97% starch, and 9.43 mg g<sup>-1</sup> tannins. Local Tritiro sorghum has higher carbohydrate, protein, and fiber content compared to other sorghum varieties from South Sulawesi and exhibits higher tannin content. These findings highlight the potential of local Tritiro sorghum as a valuable nutritional resource and its suitability for cultivation in the region, contributing to food security and sustainable agricultural practices.

##### ABSTRAK

Sulawesi Selatan telah ditetapkan oleh Kementerian Pertanian, Indonesia, sebagai salah satu provinsi utama penghasil sorgum. Varietas sorgum yang dikenal dari Sulawesi Selatan termasuk Batara Tojeng Eja, Batara Tojeng Bae, dan sorgum lokal Jeneponto. Di Kabupaten Bulukumba, Provinsi Sulawesi Selatan, Indonesia, para petani secara tradisional menanam sorgum lokal berdampingan dengan jagung. Penelitian ini bertujuan untuk mengumpulkan informasi mengenai sifat agronomi, karakteristik morfologi, komposisi nutrisi, serta kandungan fitokimia dari sorgum lokal di Desa Tritiro, Kabupaten Bulukumba. Sifat agronomi dan morfologi dianalisis melalui pengamatan pertumbuhan dan ciri fenotipik pada daun, batang, akar, malai, dan biji sorgum. Komposisi nutrisi diukur secara kuantitatif, sedangkan skrining fitokimia dilakukan baik secara kualitatif maupun kuantitatif. Hasil penelitian menunjukkan bahwa sorgum lokal Tritiro memiliki tinggi tanaman sedang, diameter batang kecil, panjang malai sedang, bentuk malai longgar, dan biji berwarna cokelat. Analisis komposisi nutrisi menunjukkan sorgum lokal Tritiro mengandung 10.11% protein, 0.19% lemak, 86.73% karbohidrat, 68.97% pati, dan 9.43 mg g<sup>-1</sup> tanin. Sorgum lokal Tritiro memiliki kandungan karbohidrat, protein, dan serat yang lebih tinggi dibandingkan dengan varietas sorgum lain dari Sulawesi Selatan serta menunjukkan kadar tanin yang lebih tinggi. Temuan ini menyoroti potensi sorgum lokal Tritiro sebagai sumber nutrisi yang berharga dan kesesuaiannya untuk budidaya di wilayah tersebut, yang berkontribusi pada ketahanan pangan dan praktik pertanian berkelanjutan.

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## INTRODUCTION

Sorghum is gaining recognition as a promising agricultural crop due to its nutritional benefits, which support health and reduce dependency on rice consumption. Its suitability for Indonesia's climate, characterized by drought tolerance and adaptability to tropical temperatures, makes it a valuable crop (Suryaningsih & Irhas, 2014; Winarti et al., 2020). Sorghum exhibits lower evapotranspiration rates compared to maize, making it suitable for semi-arid and saline environments (Wahyono et al., 2019). Research by Klocke et al. (2014) highlighted sorghum's stable yields over years (2006-2010) despite variations in evapotranspiration, contrasting with maize, which shows higher sensitivity to water stress.

Furthermore, sorghum grains contain higher levels of protein, carbohydrates, minerals, and vitamins compared to rice. Additionally, being gluten-free makes sorghum an attractive substitute for wheat flour in food industries (Cole et al., 2017; Przybylska et al., 2019; Trikoesoemaningtyas et al., 2017). The utilization of sorghum flour in various food products is expanding, with potential applications in pasta, dried noodles, bread (Rumler et al., 2024), cakes, cookies, instant porridge, and traditional foods (Setiarto et al., 2017; Widowati & Luna, 2022). According to Farrah et al. (2022) and Noerhartati et al. (2020), sorghum flour can substitute wheat flour by 50-90% in cookies, 30-50% in cakes such as nagasari and mendut, 80-100% in bread, and 30-50% in pasta.

The Indonesian Ministry of Agriculture has launched a sorghum development program (2022-2024), focusing on its utilization as food, animal feed, and biofuel. In 2022 alone, 27 national sorghum varieties were introduced, derived from previous breeding efforts and local sorghum varieties. Local sorghum varieties, serving as germplasm, play a crucial role in developing high-yielding varieties with desired grain characteristics (Mukkun et al., 2021). South Sulawesi has been identified as a key province for sorghum production. In Bulukumba Regency, specifically in Tritiro Village, sorghum is cultivated alongside maize by local farmers. However, the adoption of sorghum as a primary crop is limited due to the scarcity of sorghum seeds provided by local governments. Although some sorghum varieties from South Sulawesi, such as Batara Tojeng Eja, Batara Tojeng Bae, and local varieties from Jeneponto, are known (Widowati & Luna, 2022), information regarding local sorghum varieties from Bulukumba Regency remains sparse. Therefore, studying the agronomic characteristics and nutritional content of local sorghum from Tritiro Village is crucial to unlock its potential.

Agronomic traits are pivotal in evaluating crop productivity potential (Putra et al., 2015), serving as markers in sorghum variety selection and providing insights into sorghum's resilience to nutrient deficiencies (Mohammed et al., 2015; Trikoesoemaningtyas et al., 2017). Morphological characteristics also reflect essential properties such as resistance to fungal infections (Saniaty et al., 2016), drought stress (Sulistiyowati et al., 2022), and phenolic compound content (Punia et al., 2021; Xiong et al., 2019). Understanding agronomic and morphological traits is critical for enhancing sorghum genotypes under various environmental conditions.

Despite the existing body of research on sorghum in Indonesia, several significant gaps persist. Detailed information on local sorghum varieties specific to Bulukumba Regency, such as those from Tritiro Village, remains largely undocumented. Additionally, while general trends indicate sorghum's resilience to water stress compared to maize, specific studies examining local sorghum varieties under varying water stress conditions in Indonesia are notably lacking. Furthermore, despite the growing interest in sorghum flour as a substitute for wheat flour, comprehensive studies comparing the nutritional content of sorghum flour and grains from Tritiro Village with other sorghum varieties across Indonesia are limited. Lastly, the adoption of modern cultivation techniques for sorghum in Bulukumba, particularly among local farmers, remains largely unexplored. Addressing these gaps is crucial for advancing the understanding and utilization of local sorghum varieties, thereby contributing to the sustainable development of sorghum agriculture in South Sulawesi. This study seeks to enhance food security and nutritional sustainability for the local population through comprehensive research and practical applications.

## MATERIALS & METHODS

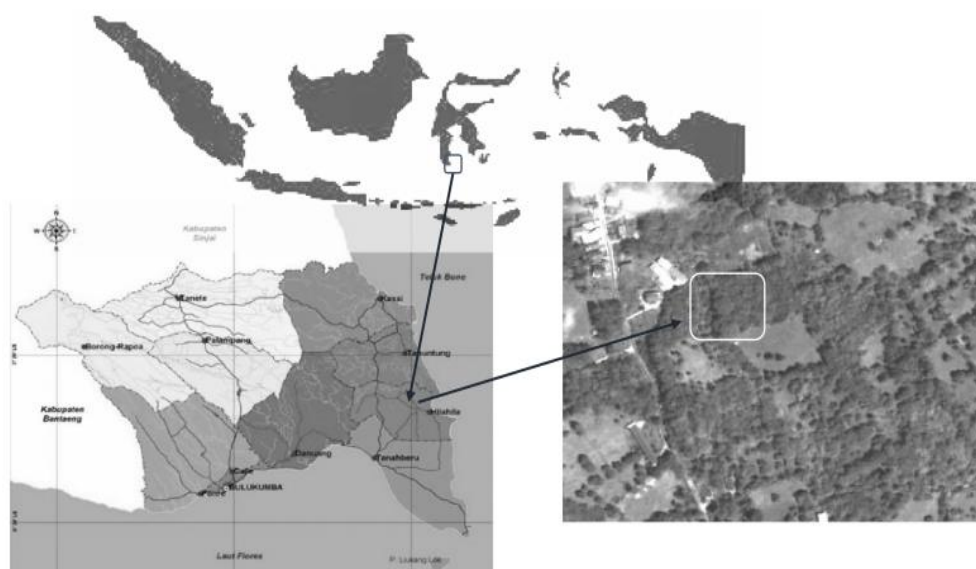
### *Materials*

Chemicals used in this study were purchased from a licensed chemical supplier with analytical grade. The chemicals included  $\text{FeCl}_3$ ,  $\text{NaOH}$ ,  $\text{HCl}$ , Mayer's reagent, and Wagner's reagent, which were used for phytochemical screening of sorghum flour.

### *Study area and plant material*

The sorghum plants used in this study were obtained from several farmers in Tritiro Village, Bulukumba Regency, South Sulawesi Province, as shown in Figure 1. Tritiro Village covers an area of approximately 700 hectares and primarily cultivates crops such as maize, coconut, pepper, peanuts, and cashew nuts. Sorghum was commonly cultivated alongside maize. The village was situated in lowland areas ranging from 0 to 25 meters above sea level (masl), with elevations reaching up to 500 masl. The average monthly rainfall was 152 mm, with an average of 10 rainy days per month. The dry season typically occurred between October and March, while the rainy season spanned from April to September.

Sorghum planting by farmers in Tritiro Village took place in late September 2021, with harvesting conducted in December and January 2022. Sorghum plants required approximately 95 days from planting to harvest. Plant materials used in this study included various parts of the sorghum plant such as leaves, stems, roots, and panicles obtained directly from farmers.



**Figure 1.** The sampling location of local sorghum in Tritiro Village, Bulukumba Regency ( $5^{\circ} 30'00''\text{S}$   $120^{\circ} 25'46''\text{E}$ ).

### *Sample collection*

The sorghum sampling process utilized purposive sampling, involving data collection from specified locations by querying local farmers regarding the cultivated sorghum types. Morphological characterization involved observing vegetative parts (leaves, stems, and roots) and generative parts (sorghum panicles). Sorghum panicles, comprising sorghum seeds, were manually threshed and subsequently sun-dried for three days. Each sorghum seed detached from the panicle was ground using a mortar and further processed into sorghum flour using a simple grinder (Noerhartati et al., 2020).

### *Agronomic and morphological characterization*

Agronomic and morphological characterization involves observing the vegetative and generative phases of sorghum plants across various parts such as leaves, stems, roots, and panicles. These plant traits are categorized into quantitative

and qualitative characteristics. Quantitative traits include leaf length (cm), leaf width (cm), leaf angle ( $^{\circ}$ ), stem diameter (cm), plant height (cm), tiller number, panicle length (cm), seed diameter (cm), seed height (cm), seed width (cm), and seed thickness (cm). Qualitative traits encompass leaf color, leaf shape and tip, leaf margin shape, leaf opening, leaf blade, leaf surface, leaf vein shape and color, presence of leaf collar, root shape, panicle shape, seed color and shape, husk color and size, grain hardness, and susceptibility to plant diseases (Saniaty et al., 2016; Slamet et al., 2020; Sondang & Yulensri, 2021). Characterizing agronomic and morphological traits involves meticulous observation and measurement, providing valuable insights into the growth, development, and resilience of sorghum varieties under various environmental conditions.

#### *Nutritional analysis*

Nutritional analysis of sorghum involved quantitative measurements of moisture content, protein, fat, ash, carbohydrates, crude fiber, starch, and tannin content. Samples used in this study included whole sorghum grains and sorghum flour. Nutrient content was determined using methods outlined in Mukkun et al. (2021).

#### Moisture content

Sorghum grains were analyzed for moisture content using the thermogravimetric method. Approximately 1.0 g of sorghum grains was placed in a petri dish and heated at 105°C for 24 hours. The percentage of moisture content was calculated based on the weight difference before and after heating.

#### Protein content

The Kjeldahl method was employed to determine protein content in sorghum flour. About 0.2 g of the flour sample was digested with  $K_2SO_4$ ,  $HgO$ , and  $H_2SO_4$ , followed by distillation and titration with 0.02 M HCl to quantify the protein content.

#### Fat content

The Soxhlet extraction method was used to measure fat content in sorghum flour. Approximately 5.0 g of flour was continuously extracted with hexane for several hours. The fat content was calculated using the weight difference before and after extraction.

#### Ash content

Sorghum flour was subjected to ash content analysis by heating 5.0 g of flour in a heat-resistant container. After acid digestion and filtration, the remaining residue was dried, and the ash content was determined gravimetrically.

#### Carbohydrate content

Carbohydrate content was calculated by subtracting the sum of moisture, protein, fat, and ash contents from 100%. This provided the percentage of carbohydrates present in the sorghum flour.

#### Crude fiber content

Crude fiber content was determined by incubating 100 g of sorghum flour with distilled water, followed by centrifugation and treatment with NaOH. The precipitate was dried and weighed to quantify the crude fiber content.

#### Starch content

Starch content was analyzed by centrifuging 2.0 g of sorghum flour and treating the precipitate with HCl. The starch content was calculated based on the weight of the residue obtained after the treatment.

#### Tannin content

Tannin extraction involved incubating 5.0 g of sorghum flour with 70% ethanol, followed by titration with potassium permanganate to quantify tannin content.

### *Phytochemical screening*

Phytochemical screening was qualitatively conducted to determine the presence of tannins, flavonoids, saponins, and alkaloids in sorghum flour. The analysis of phytochemical content in sorghum flour followed the methods outlined in the study by Irawan et al. (2022). Phytochemical screening provides essential qualitative insights into the bioactive compounds present in sorghum flour, contributing to its potential health benefits and applications in various industries.

#### Tannin test

A 1.0 mL aliquot of concentrated sorghum flour extract was mixed with 1.0 mL of 1% FeCl<sub>3</sub> solution in a test tube. The formation of a bluish-red, bluish-green, or greenish-black color upon addition of FeCl<sub>3</sub> indicated the presence of tannins in the sample.

#### Flavonoid test

A 1.0 mL aliquot of concentrated sorghum flour extract was placed in a test tube and then treated with 10% NaOH solution. The appearance of an orange or orange-yellow coloration upon reaction with NaOH indicated the presence of flavonoids.

#### Saponin test

0.5 g of sorghum flour was mixed with 10 mL warm distilled water in a test tube, then agitated manually for 10 minutes and allowed to settle. The mixture was then added with 2.0 N HCl dropwise. The presence of consistent frothing on the surface for 30 minutes indicated the presence of saponins.

#### Alkaloid test

A 1.0 mL aliquot of concentrated sorghum flour extract was mixed with 6.0 mL of 1% HCl and heated for several minutes. Then, 1.0 mL of the sample was transferred into two separate test tubes. One test tube was treated with Mayer's reagent and the other with Wagner's reagent. The formation of a cloudy precipitate indicated the presence of alkaloids in the sample.

## RESULTS & DISCUSSIONS

### *Agronomic and morphological characteristics of local sorghum plants*

The agronomic and morphological characteristics of local sorghum plants were observed during both the vegetative and generative phases (see Table 1 & Table 2). The vegetative parts included the leaves, stems, and roots, while the generative parts comprised the panicles and seeds. Morphological characteristics were analyzed qualitatively and quantitatively. Qualitative traits served as distinct morphological markers of the variety, controlled by monogenic genes, making them less influenced by environmental factors. These traits included leaf color, leaf shape and apex, leaf margin shape, the number of fully opened leaves, ligule characteristics, leaf surface texture, midrib shape and color, presence of leaf collar, root shape, panicle shape, seed color and shape, husk color and size, lodging resistance, and disease susceptibility (Saniaty et al., 2016; Slamet et al., 2020; Sondang & Yulensri, 2021; Utami et al., 2022).

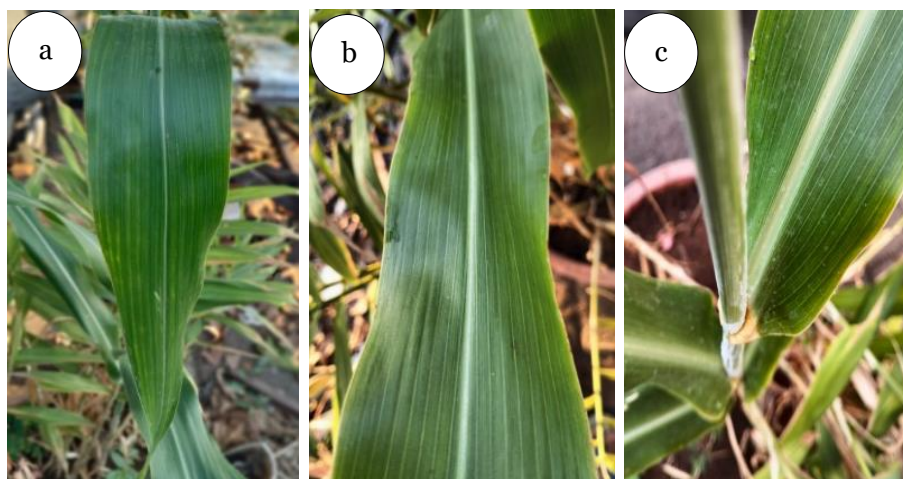
Quantitative traits, regulated by multiple genes with continuous phenotypic distribution, were more susceptible to environmental influences and included leaf length (cm), leaf width (cm), leaf angle (°), stem diameter (cm), stem height (cm), number of tillers (units), panicle length (cm), seed diameter (cm), seed height (cm), seed width (cm), and seed thickness (cm). The comprehensive analysis of these traits provided a detailed characterization of the local sorghum plants, contributing to the understanding of their agronomic and morphological properties.

Based on observations of leaf characteristics, the local sorghum plants from Tritiro Village were found to have dark green leaves with moderate color intensity. The leaves were ribbon-shaped with pointed tips and straight edges. Leaf color intensity is influenced by chlorophyll content, with darker green leaves typically having higher chlorophyll levels

compared to those with moderate or low color intensity. The leaves measured between 75 and 79 cm in length and 5.0 to 5.5 cm in width, forming angles less than 45°. Each sorghum plant had an average of 7.0 to 8.0 fully opened leaves. The leaf surface texture was observed to be smooth and non-hairy, with prominent veins contributing to the smoothness. The midribs were white, influenced by the expression of anthocyanin compounds during the germination phase (Figure 2). Additionally, the leaves had collars and ligules, completing the detailed characterization of the local sorghum plants' leaves.

**Table 1.** Morphological observations of the vegetative parts of local sorghum plants from Tritiro Village

Plant part	Morphological characteristic	Observation result
Leaf	Color	Dark green
	Shape	Ribbon
	Tip shape	Pointed
	Edge shape	Straight
	Length	75 – 79 cm
	Width	5.0 – 5.5 cm
	Angle	< 45°
	Number of fully opened leaves	8
	Presence of ligule	Present
	Surface texture	Smooth, hairless
	Vein surface	Smooth and flat
	Vein color	White
	Presence of collar	Present
	Stem	Diameter
Height		150 – 200 cm
Number of branches		2
Number of tillers		None
Root	Type	Primary root



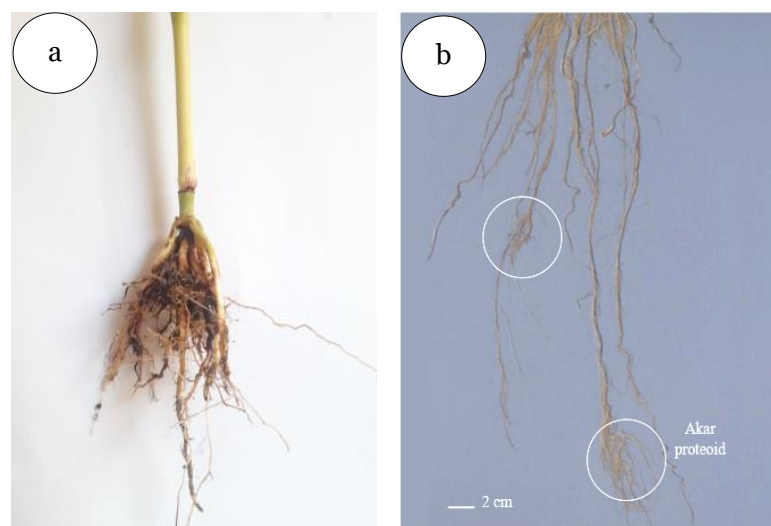
**Figure 2.** Observation of leaf parts: a) leaf tip, b) leaf edge and surface, c) leaf growth after planting period

Leaf characteristics in sorghum are often crucial indicators of the quality of the panicle that will be produced. The leaves play a vital role in the transport of assimilates resulting from photosynthesis to the panicle. Organic compounds such as ascorbic acid can be found in sorghum leaves. Ascorbic acid is an antioxidant whose levels can be induced by environmental stress. High levels of ascorbic acid may indicate tolerance to environmental stress (Ogbaga et al., 2016). Observations of the leaves, stems, and roots are presented in Table 1.

The number of leaves in sorghum is closely related to the availability of nutrients, the photosynthesis process, and the amount of assimilates produced. Garfansa et al. (2021) state that the assimilate levels in vegetative parts differ from those in the nutrient storage organs of the plant. Therefore, to determine the assimilate levels, it is necessary to measure the length, width, and number of leaves. Rahman et al. (2022) adds that, in addition to assimilate levels, genetic factors and environmental conditions of the sorghum growing area also influence leaf size. Sorghum planted with wider spacing allows for higher exposure to sunlight and relatively low nutrient competition compared to sorghum planted with closer spacing. Sulistyowati et al. (2022) found that there is a decrease in leaf area, leaf length, and leaf width in response to environmental drought stress.

The characteristics of the sorghum stem were categorized based on Elangovan et al. (2014). Measurements indicated that the sorghum stem has a diameter of less than 2.0 cm, categorizing it as having a small diameter. The plant height was moderate, ranging from 150 to 200 cm, and the number of branches was two. The height of the sorghum stem can be influenced by the rate of flag leaf formation during its generative phase. The flag leaf serves as the primary photosynthetic organ and typically emerges as the terminal leaf before panicle development occurs (Razaek et al., 2021). Stem height and diameter are critical selection criteria in sorghum breeding, as they determine the plant's lodging resistance. Sorghum with larger stem diameters is sturdier and more resistant to lodging, and is more competitive in nutrient acquisition. Conversely, sorghum plants with shorter, erect, and stiff stems are easier to harvest compared to taller sorghum plants (Rahman et al., 2022; Saniaty et al., 2016).

The root system of sorghum consisted of primary roots at the first node of the stem base, secondary roots, and lateral roots (Figure 3a). As the main organ for nutrient absorption, the morphology and physiology of roots were greatly influenced by abiotic stress factors. Sorghum, being one of the agricultural crops that thrived in dryland areas, exhibited root morphological adaptations under nutrient deficiency conditions by increasing root diameter and forming proteoid roots. Proteoid roots were characterized by the formation of clusters of roots in close lateral proximity with limited growth (Figure 3b). The development of proteoid roots was an adaptation mechanism of sorghum in environments with low availability of phosphorus and nitrogen (Mandasari et al., 2020; Wasaki et al., 2018). According to Abreha et al. (2022), sorghum genotypes with long and extensive root systems had higher survival rates because their root systems could penetrate deeper soil layers to access moisture.

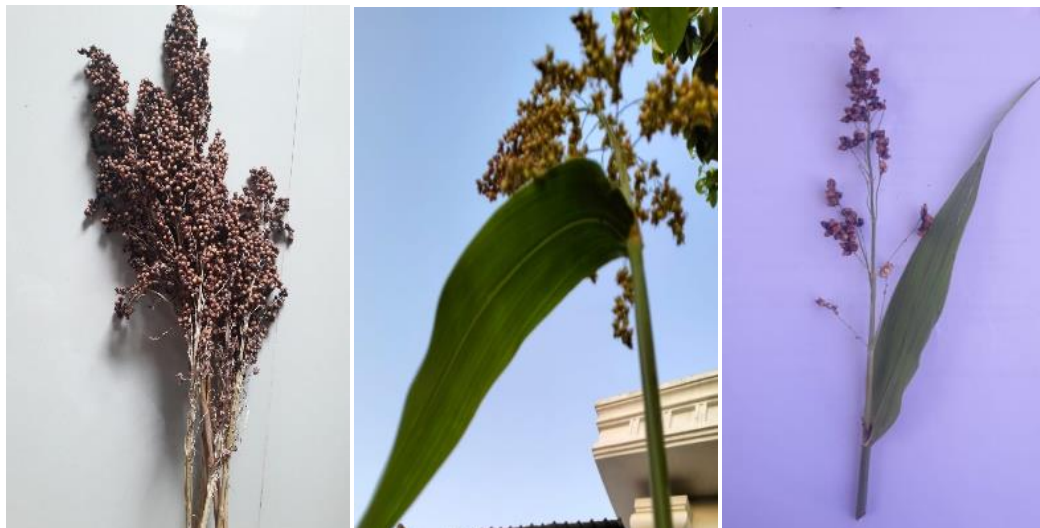


**Figure 3.** Observation of sorghum root system: a) primary, secondary, and lateral roots, b) proteoid root formation (Mandasari et al., 2020).

Physical and chemical conditions of soil such as pH, nutrient availability, and soil texture significantly influence the diversity of sorghum plants. Soil pH levels correlate with nutrient availability, with sorghum requiring soil conditions ranging from neutral to slightly acidic, typically between pH 5.5 and 7.6 (Mukkun et al., 2021). In this study, morphological adaptations of roots, such as measuring root length, diameter, and observing proteoid roots, were not conducted. Therefore, the impact of nutrient conditions in the surrounding environment on the local sorghum plants in Tritiro Village remains unknown. Table 2 presents observations on the generative parts of local sorghum plants from Tritiro Village, including panicle length, shape, neck characteristics, peduncle position, panicle type, seed color, shape, size, thickness, and glume color and size.

**Table 2.** Observations on the generative parts of local sorghum plants from Tritiro Village

Plant part	Character	Observation
Panicle	Length	27 - 32 cm
	Shape	Pyramidal
	Neck	Prominent, greenish
	Density	Loose
	Position of peduncle	Apical
	Type	Single
Seed	Color	Brown
	Shape	Elliptical
	Size	
	Diameter	0.3 – 0.5 cm
	Height	0.3 – 0.5 cm
	Width	0.3 – 0.4 cm
Glume	Thickness	0.3 cm
	Color	Dark brown
	Size	Short



**Figure 4.** Characteristics of local sorghum panicles from Tritiro Village

Local sorghum from Tritiro Village exhibits medium panicle length, ranging from 27 cm to 32 cm, with a pyramidal shape, a prominent green neck, and a loose panicle density (Table 2). In sorghum cultivation, tightly packed panicles are considered a superior commodity because panicle density positively correlates with high seed yield. However, the downside is that dense panicles have a higher susceptibility to fungal infections due to the more humid conditions within

the panicle (Saniaty et al., 2016). Nonetheless, research by Rahman et al. (2022) indicates that the density, length, and diameter of sorghum panicles do not always reflect the number of seeds per panicle, although panicle length does influence the number of potential seeds. The peduncle position of local sorghum panicles is apical, with a single panicle per stalk (Figure 4).



Figure 5. Characteristics of local sorghum seeds with a brown color

Local sorghum seeds exhibit a brown color, an elliptical shape, and tend to be relatively thick. Sorghum with darker seed colors, such as red and brown, contain higher levels of phenolic compounds compared to lighter-colored sorghum seeds. These phenolic compounds contribute to the increased resistance of darker seeds to fungal infections (Saniaty et al., 2016). Measurements indicate that the local sorghum seeds have diameters and heights ranging from 0.3 cm to 0.5 cm, with seed widths between 0.3 cm and 0.4 cm, and a thickness of 0.3 cm (Figure 5). The hulls of sorghum seeds, which are distinctive features, can be categorized into four main groups: very short hulls covering 25%, short hulls covering up to 50%, medium hulls covering 75%, and long hulls covering 100% of the seed (Kusumawati et al., 2013). Based on observations, the hulls of the local sorghum are classified as short and have a brownish-black color (Figure 6).

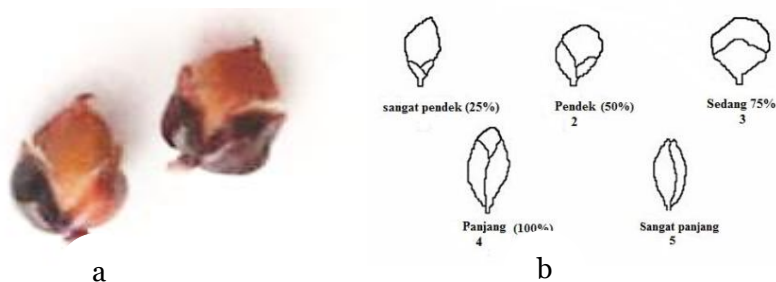


Figure 6. a) Observation of local sorghum seed hulls, b) hull trait categories based on previous study (Kusumawati et al., 2013)

*Nutritional profile of local sorghum seeds*

The nutritional composition and chemical compounds contained in local sorghum seeds are presented in Table 3. The nutrient content of sorghum, as a cereal crop, is often compared to the fiber, mineral, and protein composition found in corn and rice. The results of the nutritional composition measurements of local Tritiro village sorghum seeds were compared with three existing sorghum varieties in South Sulawesi, as well as four types of local sorghum cultivated by sorghum farmers in East Nusa Tenggara (NTT), namely black sorghum, red sorghum, brown sorghum, and white sorghum.

Variations in the nutrient composition of sorghum genotypes can support plant breeding programs. The success of sorghum cultivation in producing high-quality seeds involves the recombination and selection of genotypes with diverse genetic profiles. The nutrient composition of sorghum is significantly influenced by the interaction between genotype and environment (Queiroz et al., 2015). According to Table 3, the protein content of local Tritiro sorghum is 10.11%, fat

content is 0.19%, carbohydrate content is 86.75%, fiber content is 4.17%, and starch and tannin contents are 68.97% and 9.43 mg g<sup>-1</sup>, respectively. Local Tritiro sorghum had higher carbohydrate, protein, and fiber contents compared to the three sorghum varieties from South Sulawesi. Additionally, compared to local NTT sorghum, Tritiro sorghum had higher carbohydrate and fiber contents. Ogbaga et al. (2016) reported that drought stress can lead to increased levels of glucose and amino acids.

**Table 3.** Nutritional composition and tannin content of local Tritiro sorghum seeds

Parameter	Nutritional composition and tannin content (%)							
	Local sorghum Tritiro (This Study)	Known South Sulawesi sorghum varieties (Widowati & Luna, 2022)			Local sorghum from East Nusa Tenggara (Mukkun et al., 2021)			
		Batara Tojeng Eja	Batara Tojeng Bae	Jeneponto	Red	Black	Brown	White
Moisture content	2.40	9.91	9.01	8.72	9.91	8.65	9.06	8.55
Protein	10.11	9.02	9.17	9.35	10.16	12.73	9.03	10.32
Fat	0.19	3.80	3.10	3.30	1.98	2.66	3.28	1.56
Ash content	0.57	3.35	3.16	2.62	-	-	-	-
Carbohydrates	86.73	73.92	75.56	75.99	73.81	70.24	72.91	74.64
Fiber	4.17	3.92	4.84	4.30	3.10	2.02	2.97	3.25
Starch	68.97	-	-	-	98.25	96.43	99.46	99.76
Tannin	9.43	10.6	6.66	3.67	2.59	0.85	5.49	1.23

Note: (-) data not available

Sarshad et al. (2021) and Abreha et al. (2022) also reported that drought stress increases total protein and soluble carbohydrate contents while affecting the digestibility of sorghum nutrients. The tannin composition in Tritiro local sorghum shows higher levels compared to other varieties. Balanced fertilization significantly impacts the quality of the resulting sorghum seeds. Nitrogen fertilizers can enhance sucrose content, protein levels, and sorghum growth rates. Nitrogen is essential during cell division, whereas potassium is necessary for energy conversion processes. Thus, the application of nitrogen and potassium fertilizers plays a crucial role in improving sorghum biomass and nutrient content (Widowati & Luna, 2022). Although sorghum plants can adapt to dry environmental conditions, Sarshad et al. (2021) demonstrated that successful pollination stages in sorghum depend on environmental humidity, as pollen transfer to the pistil requires sufficient moisture. Proper irrigation management, tailored to the developmental stages of sorghum, is vital for successful sorghum cultivation.

Sorghum grains comprise proteins such as albumin, globulin, and glutelin, which are the primary components of total sorghum protein. The chemical structure of glutelin is resistant to enzymatic hydrolysis in the digestive tract, resulting in slower protein absorption in the body. Like other cereal crops, sorghum proteins are low in the amino acid lysine but high in leucine content. The imbalance in lysine and leucine concentrations can lead to vitamin B3 deficiency (Proietti et al., 2015). Additionally, the carbohydrate content in sorghum is stored in the form of amylose and amylopectin (Cardoso et al., 2015; Khalid et al., 2022).

Despite its rich nutritional composition, sorghum contains anti-nutritional factors (ANFs) that can decrease nutrient intake and cause digestive disturbances. These anti-nutritional factors include phenolic compounds and phytic acid. Tannins and phytic acid, common in higher plants, cereals, and legumes, are phenolic compounds that tend to form complexes with macromolecules like carbohydrates, proteins, and enzymes. This complex formation reduces the digestion rate of these molecules in the digestive tract (Proietti et al., 2015). Fermentation technology using lactic acid bacteria has been shown to reduce anti-nutritional factors and enhance the nutritional composition of sorghum






(Mohapatra et al., 2017). Additionally, the use of phytase enzymes can increase the solubility of phytic acid in the digestive tract, improving nutrient absorption (Rebellato et al., 2020).

*Phytochemical content of local sorghum plants*

Phytochemical testing was conducted using sorghum seeds processed into sorghum flour to increase the surface area. The sorghum flour was then macerated for 3 x 24 hours using 96% ethanol. The phytochemical testing served as an initial method to determine the presence of secondary metabolites in sorghum seeds, including tannins, flavonoids, saponins, and alkaloids. This qualitative test involved observing color changes to indicate the presence of these compounds.

The phytochemical test results of the ethanol extract of sorghum seeds are presented in Table 4. The results indicated that the presence of tannins in the sorghum seeds was confirmed by the formation of a dark green color when tested with 1% FeCl<sub>3</sub>. The presence of flavonoids was confirmed by the formation of an orange-brown color. The saponin test, which utilized distilled water and HCl, resulted in consistent foam formation for more than 30 minutes, indicating the presence of saponins. Similarly, the alkaloid test showed positive results, evidenced by the formation of a turbid brown mixture, confirming the presence of alkaloids in the sorghum seeds.

**Table 4.** Phytochemical screening results of ethanol extract of sorghum flour

Secondary metabolite	Reagent	Observed Result	Remark	Presence Indicated
Tannins	FeCl <sub>3</sub> 1 %		Dark green color	Positive
Flavonoids	NaOH 10 %		Orange-brown color	Positive
Saponins	Distilled water, HCl		Consistent foam formation	Positive
Alkaloids	Mayer		Turbid brown mixture	Positive
	Wagner			

Tannins are a group of heterogeneous polyphenol polymers characterized by their astringent taste, varying molecular weights, and diverse complexities (Piluzza et al., 2014). The World Health Organization (WHO) recommends a maximum tannin content of 0.5% in sorghum seeds and 0.3% in sorghum flour (Palacios et al., 2021). From an agronomic perspective, tannins offer the advantage of protecting plants against birds, insects, and fungal attacks (Seyoum et al., 2016). Polyphenols in sorghum predominantly exist as condensed tannins (de Oliveira et al., 2017), which provide several health

benefits, including antioxidant, antitumor, and lipid-lowering properties, as well as cardiovascular disease prevention. The procyanidin content in sorghum has been reported to range from 10.6 to 40.0 mg/g, although this varies depending on the variety (Yu et al., 2018).

Flavonoid compounds in sorghum are primarily found in the outer layer of the seeds. Therefore, their concentration and profile are associated with the seed coat color, seed coat thickness, and the presence of the testa. The main flavonoids in sorghum are anthocyanins, a group of anthocyanidin glycosides. Anthocyanins, found in plant-derived foods, impart color to fruits and flowers (Espitia-Hernández et al., 2020). Due to their antioxidant activity, anthocyanins possess various biological properties, including the ability to prevent diseases related to oxidative stress, such as coronary heart disease and cancer (Penarrieta et al., 2014).

Saponins are characterized by their foaming properties; when reacted with water and shaken, they produce a foam that can persist for an extended period. In this study, it was observed that the foam persisted for more than 30 seconds, albeit in small quantities. This indicates that saponins are present in sorghum seeds in limited amounts. Saponins have a bitter taste and can cause sneezing and irritation of mucous membranes. They exhibit a range of biological properties, including antibacterial, antifungal, and insecticidal activities (Sugiyama, 2021). Saponins are also frequently utilized as anticancer agents due to their cytotoxic activity against cancer cells (Aboutalebi & Monfared, 2016).

Alkaloids were found to be a group of organic compounds found in various parts of plants, including seeds, leaves, stems, and bark, based on research findings. It was determined that sorghum positively contained alkaloids, particularly in the seeds. Almost all alkaloids found in nature exhibit specific physiological activities. Many alkaloids are widely used in modern medicine, such as morphine, quinine, and codeine. Consequently, alkaloids are pharmacologically beneficial at low doses but can be toxic at high doses. Certain alkaloids, like strychnine, were potent toxins due to their diverse physiological effects. Therefore, alkaloids were involved in the chemical defense mechanisms of plants (Setyorini & Antarlina, 2022).

## CONCLUSION

To conclude, the local sorghum variety from Tritiro Village displays distinctive traits in its morphology, seed composition, and secondary metabolite content, including tannins, flavonoids, saponins, and alkaloids. These characteristics contribute to its nutritional richness and potential health benefits, such as antioxidant properties from flavonoids and antibacterial effects attributed to saponins. Understanding these attributes enhances our appreciation of sorghum's agricultural and medicinal potentials, motivating further research to harness its genetic diversity for sustainable crop improvement and functional food development.

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