

INVESTIGATION OF THE CULTIVATION OF GLUTEN-FREE CEREAL TEFF (ERAGROSTIS TEF (ZUCC.) TROTTER) IN CENTRAL EUROPE

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Дослідження культивування безглютенової злакової культури (Eragrostis tef (Zucc.) Trotter) у Центральній Європі. – Чобої Ю., Сабо Б., Колесник А. – Глобальні зміни клімату можуть призвести до значного підвищення середніх температур і висихання деяких територій на планеті. У 2022 році майже половина Європи пережила спекотне та посушливе літо, якого не було за останні п'ятисять років. Такі негативні зміни клімату, призводять, в тому числі, і до втрат агробіодиверсності, що є однією із основних проблем сталого розвитку. Сільськогосподарське виробництво має реагувати на ці проблеми, селекцією все нових й нових посухостійких сортів, а також культивуючи та адаптуючи культури, які за своєю суттю є посухостійкими. Тефф (Eragrostis tef (Zucc.) Trotter) — однорічний злак родини Poaceae, який широко культивується в Африці. Його борошно є основним продуктом ефіопської кухні, а тонку солому використовують як корм для тварин. Цільнозернове борошно, виготовлене з цієї культури, стає все більш важливим на ринку здорового харчування. Його використовують у виробництві різноманітних продуктів без глютену, зокрема таких, як макарони та хліб. На відміну від пшениці, кукурудзи та сорго, тефф стійкий до екстремальних кліматичних умов і добре росте як на сухих, так і на перезволожених ґрунтах. Експеримент проведений в 2022 році в демонстраційному саду Університету Нйредьгази. Сіяння були висаджені 30 травня 2022 року на чотирьох моніторингових ділянках площею по 0,5 м² кожна. Врожай зібраний 18 жовтня, отримані результати, були переведені в кг/га. Встановлена врожайність близько 5 т/га, однак не можна ігнорувати той факт, що ці показники отримані в умовах зрошення. Урожайність теффа (за умови вирахування чистоти 90%) становить у середньому 1,2 т/га. Це значно нижчі показники, ніж у традиційних зернових культур, але потенційно низькі витрати на виробництво та висока ціна продажу можуть зробити врожай конкурентоспроможним. Вага тисячі ядер становила 0,301 г, що більше, ніж в існуючих літературних відомостях.

Ключові слова: тефф, безглютенове зерно, посухостійкість, альтернативна рослина.

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Investigation of the cultivation of gluten-free cereal teff (Eragrostis tef (Zucc.) Trotter) in central Europe. – Csabai J., Szabó B., Kolesnyk A. – Climate change will lead to a significant increase in global temperatures and the drying of some areas. In 2022, nearly half of Europe experienced a hot and dry summer that was unprecedented in the last half millennium. In addition to the negative impacts of climate change, the loss of agrobiodiversity is also a major sustainability issue. Agricultural production must respond to these problems by breeding newer and newer drought-tolerant varieties and cultivating and adapting varieties that are inherently drought-tolerant. Teff (Eragrostis tef (Zucc.) Trotter) is a Poaceae family annual cereal that is widely cultivated in Africa. Its flour is a staple in Ethiopian cuisine, and its fine straw is used as animal feed. Wholemeal teff flour is becoming increasingly important in the health food market. It is used in the production of various gluten-free foods, such as pasta and breads. Unlike wheat, maize, and sorghum, teff is resistant to extreme climatic conditions and grows well in both dry and waterlogged soils. Our experiment was set up in the demonstration garden of the University of Nyiregyháza in 2022. Teff seedlings were planted on May 30, 2022. The four replicate microplots of 0.5 m² each were harvested on October 18. The yield results obtained from the measurements were converted to kg/ha. The hay yield of almost 5 t/ha seems favourable, but we cannot ignore the fact that the crop produced this yield under irrigated conditions. The grain yield (if deductions for 90% purity are made) averages 1.2 t/ha. This is significantly below our cultivated cereals, but the potentially low production costs and high selling price could make the crop competitive. The Thousand Kernel Weight was 0.301 g, which was higher than previously reported.

Keywords: teff, gluten-free grain, drought tolerance, alternative plant.

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Introduction

Climate change will lead to a significant rise in global temperatures and the drying of some areas (Steffen et al. 2018). Almost half of Europe will be affected by a hot summer drought in 2022, unprecedented in the last half millennium. A drought warning has been issued for 47 percent of Europe. It is expected that the phenomenon will persist on the old continent not only in the short term but also in the long term. Such regions include northern Italy, southeast France, and parts of Hungary. In Hungary, more than 80 percent of the territory has been affected by severe or serious drought, and in some areas it has been impossible to harvest anything (Kis et al. 2022; Newburger 2022; Flór 2022).

In addition to the negative impacts of climate change, the loss of agrobiodiversity is also a major sustainability issue. Of the 30,000 known crop species, only five cereal species currently provide more than 50% of the world's energy: bread wheat (*Triticum aestivum*), rice (*Oryza sativa*), sorghum (*Sorghum bicolor*), millet (*Panicum* sp.), and maize (*Zea mays*). Over-exploitation of these priority species could cause large-scale genetic losses (Barretto 2021).

Agricultural production has to respond to these problems by breeding newer and newer drought-tolerant varieties, and by cultivating and adapting varieties that are inherently drought-tolerant (Mavroeidis et al. 2022; Zhang 2022; Pulvento et al. 2022). In Hungary, due to climatic changes, especially heat and a steep increase in the number of drought years, there is a significant research activity on the introduction of drought-tolerant alternative crop species, such as chickpea, amaranth (Piszkerne et al. 2017, Csabai et al. 2019).

Teff (*Eragrostis tef* (Zucc.) Trotter) is a Poaceae family annual C4 cereal that is widely farmed in Africa (D'Andrea 2008). The plant's height ranges from 25 cm to 135 cm. A spike-flowered plant. It has the smallest seeds among cereals (the weight of a thousand grains is usually 0.19–0.21 g), and the meaning of the word teff also refers to the size of the seed, meaning "lost", because if it is dropped on the ground, it is lost (Özköse et al. 2022). The flour made from its fruit is a staple of Ethiopian cuisine, and its fine straw is used as animal feed (Woldeyohannes 2020).

Teff contains 80% carbohydrates, of which 73% is starch. It has a similar average crude protein content of 8–11% compared to wheat and maize. Its amino acid composition is well balanced and higher than that of most

cereals. Teff also contains a higher proportion of lysine (3.7%), an amino acid important for muscle growth. It has a fiber content of 4.5%, much higher than maize, wheat, and sorghum (Baye et al., 2014). Teff has a crude fat content of 2.5%, which is medium compared to other cereals such as wheat and rice. However, these cereals are often refined, thereby reducing their crude fat content. Teff is also used to make wholemeal flour, which preserves the fat content originally present in teff. In addition, teff has a higher unsaturated fatty acid content (e.g. oleic and linoleic acid) than other cereals and thus has a higher nutritional value (El-Alfy et al. 2012). It also has a significantly higher mineral content than wheat, maize, and rice (Barretto 2021; Ligaba-Osena 2021; Fairweather-Tait 2002).

The cultivation of teff yields relatively low yields of between 1 and 2 metric tons per hectare, significantly lower than other cereals, including maize and wheat (Woldeyohannes 2020; Cochrane, Bekele 2018). However, its cultivation is not only justified on environmental and sustainability grounds but also needs to be considered from an economic perspective. In recent years, teff has become increasingly popular worldwide due to its attractive nutritional profile and high dietary fiber content (Barretto 2021). Hassen and colleagues (2018) reported different patterns of teff consumption by poverty level. The data show that the majority of teff consumers are high-income. In parts of Europe and North America, teff was initially imported to meet the needs of the Ethiopians living there. However, as the crop has become popular due to its wide distribution, it has also attracted the interest of consumers of different nationalities (Hassen 2018). Wholegrain teff flour is becoming increasingly important in the health food market. It is used in the production of various gluten-free foods, such as pasta and breads. In countries outside Africa, the demand for healthier foods is also driving consumers to pay premium prices for teff-based products (Lee 2018). The rise in the global popularity of the crop has led to skyrocketing overall exports and market prices, prompting the Ethiopian government to restrict exports. The rise in teff prices is also one of the reasons that several countries, including the United States, Australia, China, Cameroon, Canada, India, the Netherlands, South Africa, the United Kingdom, and Uganda, have begun developing their own production and marketing strategies in order to

compete in the expanding market (Barretto 2021; Zhu 2018; Abraham 2015).

We cannot speak about world market rates for teff because there are very few countries involved in commerce and production, and teff leaving Ethiopia is marketed as contraband since the 2018 export embargo. Between 2005 and 2012, the price fluctuated dramatically, ranging from USD 500 to 1000 per tonne, depending on the value of the Ethiopian Birr and export limitations. This price is much higher than wheat and maize, which are expected to range between USD 270 and 320 per tonne in 2022.

However, despite the economic benefits of teff, knowledge of efficient cultivation, harvesting, and processing practices still lags behind other crops (Lee 2018). Its cultivation in Ethiopia relies on manual labor, so little experience with large-scale mechanized cultivation is available.

Teff is harvested when its vegetative parts turn yellow, indicating maturity. Depending on environmental conditions, this can occur as early as 45 days after planting (Bultosa 2004). Harvesting is usually done by hand with sickles on smaller farms, while some larger producers use harvesting machines. The plants are then threshed to separate the seeds from the stems and the flakes from the seeds. After harvesting, the teff grains are usually stored to allow ripening and to break dormancy. Grain losses are usually high (25–30%) in traditional manual harvesting methods, as the grains are light and can be easily blown away by the wind (Barretto 2021).

Teff is a sustainable plant because it can live in climates where other plants cannot. Teff, unlike wheat, maize, and sorghum, is drought and flood tolerant and thrives in both dry and wet soils. It is suitable for organic farming because it has no known pests or pathogens and can survive without the use of fertilizers or pesticides. However, because teff is often produced in tropical settings (where day and night lengths are nearly identical), yields may differ if the crop is grown outside of the tropics. (Barretto 2021).

The ideal range for teff growth and development is between 15°C and 21°C. Temperatures below 10°C are not suitable for teff germination. There are two ways to start the culture. One is to sow it immediately in the open ground; the other is to prepare the seedlings and then plant them. In the first case, the yield is lower, germination is less, and seedling development is weaker and more sluggish.

Planting, on the other hand, requires a lot of manual labor. At the sowing stage, germination requires evenly distributed rainfall. For most varieties, 300–550 mm of rainfall is already adequate during the growing season (Araya 2011; Ketema 1997). Although teff is drought-tolerant, water is a major factor, as its productivity is higher under good rainfall conditions. The most suitable soil for teff is a neutral to slightly acidic soil. It is mainly planted on sandy loam soils but will also thrive on black, heavy clay soils with adequate drainage and nitrogen (Barretto 2021; Norberg 2008; Tefera, Belay 2006). Seed requirements range from 15 to 55 kg/h depending on the sowing method (Ketema 1997).

The main advantage of teff is its ability to produce high quality hay in a relatively short growing season. Teff can be planted in late spring and cut several times during the summer, with yields averaging 4–7 tons per hectare, depending on the length of the growing season (Miller 2009). The time between cuts is usually 40–50 days for the first cut and about 30 days for subsequent cuts, but this can vary from one growing area to another. Teff can also be used for grazing, but its shallow root system makes it susceptible to overgrazing (Özköse 2022; Miller 2009).

In Oregon and Washington variety trials, the relative forage quality (RFQ) of teff hay ranged from 78 to 108. On average, the quality was similar to that of full-flowering alfalfa. In other Oregon studies, at different irrigation and nitrogen rates, teff RFQ ranged from 86 to 169. Thus, teff is not a substitute for dairy-grade hay, which generally has an RFQ of 180 or higher (Norberg et al. 2008).

Teff was first grown in the United States by Ethiopian refugees in the 1980s (Crymes 2015). It's produced in at least 25 states right now, including Idaho, Kansas, and Nebraska (AgriFuture Australia 2022; Lee 2018; Davison, Laca 2010). It is mainly grown for animal feed. Teff hay costs between \$5 and \$10 per bale, depending on the grade and weight of the hay. (Hay Suppliers 2022).

In Europe, teff has been tested in the Mediterranean. The teff seeds were sown on April 19 at a row spacing of 30 cm by hand, at a seed rate of 5 kg/ha and at a depth of 1 cm. The field was irrigated five times with a sprinkler system. The total amount of water applied was 328 mm. No pest or disease occurred in the crop during the experimental period. During the experiment, the effect of organic and inorganic fertilizers on growth and yield was investigated.

Their results showed that both organic and inorganic fertilization had a positive effect on morphological parameters and yield. The results showed that inorganic fertilizer application resulted in higher plant height, stems per stem, grain yield, and straw yield (Roussis 2019).

Materials and methods

Our experiment was set up in the demonstration garden of the University of Nyíregyháza in 2022. The soil of the experimental area is humic sand. The experimental plot received 50 t/ha of mature compost in March 2022. Teff seeds were sown on 30 May 2022. We set up the experiment at the rate of 5 kg/ha (approximately 20 million germs/ha) recommended in the literature. Weed control was not necessary due to the rapid growth of the plant. No insect pests or fungal diseases were encountered during the duration of the experiment, so no chemical or agrotechnical plant protection interventions were necessary. Due to the extremely dry weather conditions, the plots were irrigated 12

times during the growing period with an occasional 10 mm water dose. The 4 replicate microplots of 0.5 m² each were harvested on 18 October. The above-ground part of the plants was cut off at 5 cm stubble height and the whole plants were dried in the University's plant production laboratory at an average temperature of 20 °C. After threshing, we measured the dried and threshed residues from the plots, dried to 14 % moisture content, and the grain yield cleaned from the husks of similar moisture content. In order to avoid significant losses during cleaning (due to the very small size of the grains), we settled for a crop purity of 90%. In the measured batches, an average of 10 percent of the grains were left with husks. The thousand kernel weight of the batches was assessed by averaging 4 times 500 kernels after weighing, which is the standard method.

Results

The results of the measurements were converted to kg/ha (Table 1).

Parcel (s.sz)	hay yield (kg/ha)	seed yield (kg/ha)	thousand kernel weight (g)
1.	5216	1410	0,297
2.	4420	1205	0,277
3.	4996	1350	0,307
4.	4678	1405	0,323
Average:	4827,5	1342,5	0,301

Fig. 1. Yield results of the teff microplot experiment (University of Nyíregyháza demonstration garden 2022)

Because of the small number of elements, the obtained findings cannot be statistically evaluated and are thus only indicative. The hay yield of almost 5 t/ha seems favourable, but we cannot ignore the fact that the crop produced this yield under irrigated conditions. Compared to alfalfa, our most commonly grown fibre fodder, the hay yield is low.

Grain yields (if deductions for 90% purity are made) average 1.2 t/ha. This is significantly below our cultivated cereals, but the potential low production costs and high selling price could make the crop competitive.

If both crop components are considered, the picture is much more favourable in terms of yield.

When examining the thousand grain weight, it can be noted that the measured values exceed those reported in the literature (Özköse et al. 2022).

Conclusions

As a result of the changing climatic conditions, we can infer that the plant is worth experimenting with in our nation. In addition to yield measurement, it will be necessary in the future to thoroughly research and modify certain aspects of cultivation technology.

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