**INTRODUCTION**

Grasslands are valued for provision of various ecosystem services having not only environmental impact, but beneficial from an agronomic perspective as they play a major role in sustainable milk and meat production (Humphreys et al., 2010; Wilkins and Humphrey, 2003). Grasslands are available for different environments and for different purposes: grazing, silage and hay and usually they are composed on the basis of knowledge about adaptation, performance and persistence of individual species and cultivars in pure stands. One of the main forage species composing pastures in Central Europe is Italian ryegrass (*Lolium multiflorum* subsp. *italicum* Lam.) where it is widely used for hay and silage production. It is very productive under intensive farming system and features high palatability thus is preferred by grazing animals (Bernard et al., 2002). Inclusion of Italian ryegrass into the pastures along with legumes and other monocot species results in higher forage quality as well as high and steady production which can already be obtained in the year of sowing (Conert, 1998; Cosgrove et al., 1999, Lenuweit und a., 2002). Though some literature sources indicate that under favourable environmental conditions it can stay in the mixtures for 5 years and more (Peeters, 2004), usually Italian ryegrass is grown as a short lived species (Casler, Nelson, 1997; Conert, 1998; Humphreys et al., 2010). In Lithuania, it is cultivated as annual or biennial and the length of the cultivation period depends environmental conditions. Low tolerance to abiotic stress, such as harsh winter condition when plants are exposed to fluctuating temperature causing repeated freezing-thawing cycles, water logging, low levels of snow insulation etc. are the main factors limiting Italian ryegrass distribution and decreasing its agricultural and commercial importance.

The projected and already ongoing climate change challenges the employed agricultural practises for food production (Meier et al., 2022). In the temperate region, where Lithuania is located, the main limiting factors for high crop productivity is rather short and moderately cool vegetative season accompanied by abiotic and biotic stresses brought by winter season (Ergon et al., 2018). Thus, when global warming results in increased annual average temperatures, shifted growing seasons leading to milder winters this could be beneficial in the form of increased potential of biomass production. But at the same time, with new possibilities and new types of stress, such as summer drought events, will occur as a consequence of uneven distribution of precipitation both during vegetative and cool seasons. Therefore, keeping profitability of the pasture systems we need to modify or make substantial changes to current farming systems or to develop the new ones (Lee 2013; Kalaugher 2017). And here the main role can be played by breeding aiming at development of varieties for improved winter survival, regrowth capacity and maximized resource use efficiency. Studying G x E interaction is the other way of identifying the optimal cultivar or species which exhibits the best adaptation, persistence and productivity at a given environment and geographical location (Dalmannsdóttir et al., 2015; Østrem et al., 2018).

Italian ryegrass breeding in Lithuania started in 1990 and more than a decade later, when the breeding programme was intensified, major achievements were attained. As a result, a tetraploid cultivar ‘Ugnė‘ has been developed and listed in National Variety List and EU Common Catalogue of Varieties of Agricultural species. It is characterized by high dry matter yield, good winter survival as well as high regrowth capacity after cuts. One of the most characteristics of the variety is its yield stability, the trait explaining capacity of variety to produce high yield under various environmental conditions. However, high stability usually compromises high productivity and thus plants bred under one condition could show high potential, but under different conditions may not exhibit expected results. Therefore, combination of these traits is what breeders aim for.

In this study we have chosen Italian ryegrass tetraploid cultivar ‘Ugnė’ and aimed at assessing its 1) productivity within and among the seasons, 2) yield stability under fluctuating weather conditions over the period of 14 years.

**MATERIALS AND METHODS**

**Plant material and experimental design**

Lithuanian origin tetraploid Italian ryegrass (*Lolium multiflorum* subsp. *italicum* Lam.) variety ‘Ugnė’ was evaluated under the field conditions at LAMMC Institute of Agriculture (55°23'N, 23°57'E) over the period of fourteen years. The experiment was set up in 6.52–9.75 m2 test plots using a randomized complete block design with three replications and considering that one experimental cycle consisted of the sowing year and one year of use. The field soil is *Endocalcari – Epihypogleyic Cambisols* (*CMg-p-w-can*), characterized by a homogeneous texture, pHKCl 7.3-7.0, humus content 1.9-2.2%, available P2O5 206–270 mg kg-1 and K2O 101-154 mg kg-1. The seeds were sown using seed drill Hege 80 at the depth of 2,0–2,5 cm, where the seeding rate was 25 kg pure live seed ha-1. The basic nitrogenous, phosphorus and potassium fertilizers were applied before the sowing (NPK 10-120-180) and at the beginning of each vegetative season (N60) as well as after the cuts (N45) except the last one.

**Determination of productivity and quality characteristics**

The productivity was determined during the whole vegetative season, when plots were harvested 3-4 times per season depending on meteorological conditions. Plots were harvested with a self-propelled hay mower at about 5 cm aboveground level and biomass was weighed in the bunker of the mower. The samples of 0.5 kg of fresh biomass were dried at 105 °C in a well-ventilated oven to a constant weight and used to determine dry matter yield (DMY). The first harvest was performed at the plant heading stage (when more than 50 % of plants emerged) while subsequent harvest was carried out at intervals of 40-60 days. The winter survival, spring growth, regrowth after cuts and crown rust (*Puccinia coronifera* Kleb) and spot disease (*Drechslera* spp.) damage and were evaluated visually and scored using 1–9 score scale, where 1 represents the lowest and 9 – the highest value of the trait. The diseases were scored as 1 = no damage, 2 = trace of disease, 3 = 5%, 4 = 10%, 5 = 25%, 6 = 40%, 7 = 50%, 8 = 75%, and 9 = more than 75% of the leaves covered with disease.

The nutritive (feeding value) of the herbage was determined at the heading stage of the plants, just before the first cut. Samples were analyzed for contents of crude protein (CP), crude fibre (CF), water soluble carbohydrates (WSC) and dry matter digestibility (DMD) using a near infrared spectrometer NIRS-6500 (Perstorp Analytical, Silver Spring, Maryland, USA) (Butkutė et al., 2003).

**Meteorological data**

Lithuania is located in nemoral zone, which is characterized by a cool temperate climate and quite short growing season of 190–195 days (Metzger et al. 2012). Ten-day meteorological data of mean, minimal and maximal temperatures, precipitation and snow cover were recorded at meteorological station in Akademija (55°23'N, 23°57'E) over the period of 2009 – 2022. The considered agroclimatic indices were growth period (GP), autumn hardening (AH) and winter period (WP). GP was assumed to start after the mean temperature Tmean ≥ 5°C stayed for 5 days in a row and lasted until each harvesting. AH started when Tmean ≤ 5°C for 5 days in a row and ended at the first day of Tmin ≤ -10°C. Cold days were considered when Tmin ≤ -15°C, while the warm days – when Tmean ≥ 0°C. Degree days were calculated with the base temperature Tb = 5°C (Bélanger et al. 2002; Thorsen and Höglind 2010). Meteorological conditions varied both in terms of precipitation and temperature during the period studied (Supplementary Figure 1). Although Lithuania is in the zone of excess irrigation, summer droughts are rather frequent events. The vegetative season of 2015 was dry but cool, and lack of precipitation during the season of 2018, 2019, 2020 and 2021 was accompanied by high temperature. Summer of 2022 was characterized by hot and moist weather. In contrast, summers of 2016 and 2017 were cool and moist. Particularly cold winters occurred in 2010 and 2014, while winter of 2020 and 2022 was very warm. Meanwhile, winter period of 2016-2019 featured short periods of about 3-4 weeks of cold, when the temperature dropped below -15°C and which are critical for ryegrass.

**Statistical analysis**

The statistical analysis was implemented in the open-source R statistical environment (version 4.3.1; (R Core Team 2023). Basic descriptive statistics was calculated using R package ‘metan’ function desc\_stat (Olivoto and Lúcio 2020), analysis of variance and post-hoc tests were conducted using R package ‘agricolae’ (Mendiburu and Yaseen 2020). To estimate environment effect on DMY, ANOVA and subsequently post hoc Tukey HSD test was applied. The Kruskal-Wallis test was used for analyzing the influence of year on qualitative traits and Fisher's least significant difference with Bonferroni correction was applied to test for significant differences between the trait means.