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Determination of Herbage Yield and Quality of Some Italian Ryegrass Varieties in Sivas Ecological Conditions

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Abstract
Italian ryegrass is a forage plant that can grow rapidly vegetatively, can take at least two cuts in suitable ecologies, and has a tall plant height. Italian ryegrass, an annual forage crop, is rich in minerals, protein and water-soluble carbohydrate content, good palatability, digestibility and metabolic energy value are quite high compared to herbage of medium pasture quality. Italian ryegrass is a plant that has the potential to be a solution to the roughage needs of farm animals in Turkey. In this context, the aim of this study is to determine the Italian ryegrass variety or varieties with high yield and quality suitable for Sivas ecology. Twenty-one Italian ryegrass varieties (Master, Quickston, Big Boss, Koga, Venüs, Braulio, Jivet, Medoacus, Excellent, Tornado, İlkadım, Caramba, Kartetra, Efe-82, Trinova, Hellen, Devis, Vallivert, Teanna, Rambo, Zeybek-19) were used as plant material in the experiment. Experiment was conducted at Sivas Science and Technology University, Faculty of Agricultural Sciences and Technology, Agricultural Ar&Ge Center trial area in 2022-2023 growing season. According to the data obtained, the differences between Italian ryegrass varieties were found to be statistically significant in terms of plant height, green and dry herbage yields. Plant height, green and dry herbage yields ranged between 115.0-130.7 cm, 1407-3240 kg da^{-1} and 392-976 kg da^{-1}, respectively. In terms of quality parameters of varieties, differences were also significant. The values were 11.18-14.73% for crude protein rates, 6.57-12.43% for crude ash rates, 32.9-37.7% for ADF (Acid detergent fiber) rates, 61.6-65.4% for NDF (Neutral detergent fiber) rates, 59.55-62.76% for DMD (Digestible dry matter) rates, 1.84-1.95% for DMI (Dry matter intake) rates, and 84.76-94.42 for RFV (Relative feed value) values. Among the Italian ryegrass varieties used in the research, it was determined that Excellent variety performed well in terms of herbage yield, and İlkadım, Master and Kartetra varieties performed well in Sivas conditions in terms of herbage quality.

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1. Introduction

Grasslands are important because they provide a range of ecosystem services that are useful not just to the environment but also to agriculture, as they are essential to the sustained production of meat and milk (Humphreys et al., 2010; Wilkins and Humphreys, 2003). Grasslands are found in many settings and provide a variety of functions, including hay, silage, and grazing. Their composition is often determined by the adaption, productivity, and endurance of certain species and cultivars in unadulterated stands.

Italian ryegrass (*Lolium multiflorum* subsp. *italicum* Lam.) is one of the finest fodder grass producing species in terms of yield and energy content. It is frequently employed as a component in the manufacture of silage (Worku et al., 2021; Ertekin et al., 2022). Harvesting Italian ryegrass early in the blooming season allows it to dry fast and produces a high-quality crop of hay that livestock may consume. When there is heavy rainfall, it is advantageous to postpone harvesting and provide the gathered material to animals in the form of silage. The plant has thin stems and non-coarsen structure, however after flowering, the digestibility of the hay declines. In the one cutting can provide 1500-2500 kg da^{-1} of green herbage and 500-800 kg da^{-1} of dried herbage under typical circumstances. By harvesting two to three times, one can acquire 4-6 tons of green grass and 750-1500 kg da^{-1} of dried herbage in places that receive spring rains or under irrigation (Avcıoğlu et al., 2009).

Grazing animals enjoy it, because of its high palatability and high productivity in intensive agricultural settings (Bernard et al., 2002). Incorporating Italian ryegrass into pastures with legumes and other monocot species leads to increased feed quality and consistent, high production that can be realized the year after seeding (Burns et al., 2015). Apart from its immediate agronomic advantages, it offers additional ecosystem services that improve soil health (Blanco-Canqui et al., 2015). These services include lowering leaching of nitrogen and phosphorus (Malcolm et al., 2009; Maxwell et al., 2014), which prevents water bodies from being contaminated (Aronsson et al., 2016), capturing carbon (Bolinder et al., 2007; Riley et al., 2008; Schmidt et al., 2011), strengthening soil aggregate stability (Riley et al., 2008), and, lastly, boosting the diversity and density of small fauna and biota species in the soil (Pommeresche and Løes., 2009; 2014).

Italian ryegrass is cultivated as a short-lived plant since it cannot withstand harsh winter weather; nevertheless, a study conducted by Canadian researchers reported that it may survive in mixes for four years in milder winter climates or with enough snow protection (Jung et al., 1996; Humphreys et al., 2010). It is grown as an annual or biannual in Lithuania and other Baltic nations; the duration of the growing season is determined by the climate (Kemešytė et al., 2013). Italian ryegrass's limited range and challenging cultivation are mostly caused by its low resistance to abiotic stressors including water logging, low levels of snow insulation, temperature fluctuations that result in recurrent freezing-thawing cycles, etc. (Bērziņš et al., 2020). The aim of this study was to determine the herbage yield and quality of some Italian grass varieties.

2. Materials and Methods

In the study, 21 registered Italian ryegrass varieties (Master, Quickston, Big Boss, Koga, Venüs, Braulio, Jivet, Medoacus, Excellent, Tornado, İlkadım, Caramba, Kartetra, Efe-82, Trinova, Hellen, Devis, Vallivert, Teanna, Rambo, Zeybek-19) obtained from some companies were used as plant material. The experiment was conducted in the 2022-2023 growing season at Sivas Science and Technology University, Faculty of Agricultural Sciences and Technology, Agricultural Ar&Ge Center trial area, according to the randomized block trial design, with three replications. The parcel area in the experiment was made to be 5 m long and 6 rows. Sowing was done in the first week of October, using 20 cm row spacing and 4 kg of seeds per decare. DAP fertilizer was applied to the area where the experiment was conducted, at the rate of 4 kg nitrogen and 10 kg

phosphorus (P_2O_5) per decare, upon planting. When the plants reached a height of approximately 30 cm, top fertilization was applied with 6 kg of nitrogen per decare.

Table 1. Precipitation, temperature and relative humidity values of the period of the experiment

Months	Total Precipitation (mm)		Average Temperature (°C)		Average Relative Humidity (%)	
	2022-2023	Long Term	2022-2023	Long Term	2022-2023	Long Term
October	16.6	19.0	11.6	12.5	62.8	57.6
November	39.6	32.3	6.6	6.1	74.2	69.9
December	23.8	29.8	3.0	2.7	86.1	79.8
January	7.2	46.1	0.9	-2.0	87.3	74.0
February	43.8	35.4	-3.6	0.6	92.4	71.2
March	107.6	44.2	6.4	2.5	93.0	64.7
April	74.8	23.2	9.1	11.1	92.8	50.0
May	56.4	18.9	13.0	13.9	93.6	53.8
June	51.4	77.7	17.3	18.6	95.3	55.2
Total/Aver.	**421.2**	**326.6**	**7.1**	**7.3**	**86.4**	**64.0**

The province of Sivas is characterized by a continental climate, with hot, dry summers and cold, snowy winters. Table 1 provides key climate characteristics during the research period, including temperature, precipitation, and humidity. The lowest recorded average temperature was -3.6 °C in February, and the highest recorded average temperature was 17.3 °C in June. Between October (2022) and June (2023), there was 421.2 mm of precipitation overall, which was more than the long-term average of 326.6 mm. Month-by-month variations in the average relative humidity value ranged from 62.8% to 95.3%, above the long-term average of 64.02%.

Table 2. Physical and chemical properties of the soil of the trial site

Depth	Texture	pH	Lime (% $CaCO_3$)	Salinity (%)	P_2O_5 (kg da^{-1})	K_2O (kg da^{-1})	Organic matter (%)
0-30 cm	Silty clay loam	7.28	19.6	0.33	3.40	93.59	1.7

Table 2 provides the experimental site's chemical and physical characteristics. The soil in the Sivas location was silty clay loam with a pH of 7.28. It was also notable for having a low phosphorus (P_2O_5) content (3.40 kg da^{-1}), low organic matter (1.7%), high potassium (K_2O) content (93.59 kg da^{-1}), lime content (19.6 %) and salt contents (0.33 %). The field was adequately drained, and there was no groundwater issue during the investigation.

Harvesting time was done in the second week of June. Plant height of 10 plants from each plot planted in the experiment was measured and the average was taken. In addition, after removing the outer row in each parcel, the weights of the plants harvested from the remaining four rows in the middle were taken and the weights obtained were converted into decare calculations. 500 g of plant samples taken from each parcel were weighed after being left to dry at 70 ^{0}C for 48 hours and the dry matter ratio was determined. Then, the dry matter ratios were multiplied by the green herbage yield and the dry herbage yield per decare was determined. Dry herbage samples of the Italian ryegrass varieties were ground in mill and passed through 1 mm sieve for chemical analysis. Crude ash ratio of Italian ryegrass samples was determined by burning at 550 ^{0}C for 8 hours (AOAC, 1990). Crude protein analyses were performed by the methods specified in AOAC (2003). The ADF and NDF constituting the cell wall were performed by the method specified in Van

Soest (1963) and Van Soest and Wine (1967). Relative feed value (RFV), dry matter digestibility (DMD) and dry matter intake (DMI) of Italian ryegrass samples were calculated according to the formulas (Morrison, 2003). DMD % = 88.9 - (0.779 x ADF %); DMI % = 120 / NDF %; RFV = (DDM % x DMI %) /1.29.

The analysis of the data obtained was made in the Jump-Pro13 statistical package program and the differences between the averages were compared according to the Tukey test. Correlation analysis and color map were made in Jump-Pro13 and Biplot graphics in Genstat 12th (Copyright 2011, VSN International Ltd.).

3. Results and Discussion

Plant height (PH), green herbage yield (GHY), dry herbage yield (DHY), crude ash (CA), crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), dry matter digestibility (DMD) and dry matter intake (DMI) ratios and relative feed value (RFV) values determined in the samples of some Italian ryegrass varieties were found to be statistically significant at the 1% level (Table 3).

Table 3. Average values of herbage yield and quality characteristic of Italian ryegrass varieties

Varieties	PH (cm)	GHY (kg da^{-1})	DHY (kg da^{-1})	CP (%)	CA (%)	ADF (%)	NDF (%)	DMD (%)	DMI (%)	RFV
Big boss	128.2^{a-c}	2027^{fg}	635^{ef}	11.18^{ı}	6.91^{cd}	37.7^{a}	65.4^{a}	59.55^{ı}	1.84^{fg}	84.76^{h}
Braulio	123.1^{e-g}	1783^{h}	577^{f-h}	11.35^{hı}	8.89^{bc}	37.1^{ab}	63.3^{b-g}	60.04^{hı}	1.90^{a-e}	88.26^{d-h}
Caramba	129.1^{ab}	2057^{f}	615^{e-g}	11.83$^{g-ı}$	7.34^{cd}	36.1^{b-f}	64.1^{a-e}	60.80^{d-h}	1.87^{c-g}	88.28^{d-h}
Devis	125.0^{c-f}	2125^{d-f}	674de	12.09$^{f-ı}$	6.61^{d}	37.1^{ab}	65.4^{a}	60.03^{hı}	1.84^{g}	85.42^{gh}
Efe 82	130.7^{a}	2218^{c-e}	621^{e-g}	13.36^{bc}	7.42^{cd}	34.4$^{g-ı}$	63.6^{a-f}	62.12^{a-c}	1.89^{b-g}	90.93^{a-e}
Excellent	119.6^{gh}	3240^{a}	976^{a}	13.07^{c-f}	7.29^{cd}	35.1^{d-h}	63.4^{b-g}	61.55^{b-f}	1.89^{a-f}	90.35^{b-f}
Hellen	124.1^{d-f}	2164^{d-f}	679de	11.78$^{g-ı}$	6.72^{d}	35.3^{c-h}	62.5^{e-g}	61.41^{b-g}	1.92^{a-c}	91.53^{a-d}
İlkadım	118.3^{hı}	2601^{b}	799^{bc}	14.73^{a}	6.86^{cd}	32.9^{ı}	61.9^{fg}	62.76^{a}	1.94^{ab}	94.42^{a}
Jivet	130.9^{a}	2720^{b}	728^{cd}	13.23^{b-d}	6.57^{d}	33.9^{hı}	62.6^{d-g}	62.50^{ab}	1.92^{a-d}	92.94^{a-c}
Kartetra	124.9^{c-f}	2264^{cd}	639^{ef}	14.22^{ab}	6.90^{cd}	33.7$^{f-ı}$	61.6^{g}	61.89^{a-d}	1.95^{a}	93.49^{ab}
Koga	126.4^{b-e}	2108^{ef}	531^{hı}	11.52^{hı}	12.43^{a}	36.5^{a-d}	64.3^{a-e}	60.44$^{f-ı}$	1.87^{c-g}	87.56^{e-h}
Master	122.5^{e-g}	2368^{c}	827^{b}	13.15^{c-e}	7.33^{cd}	35.0$^{e-ı}$	61.6^{g}	61.64^{a-e}	1.95^{a}	93.14^{a-c}
Medoacus	123.2^{e-g}	1489^{ıj}	481^{ı}	11.89$^{g-ı}$	6.65^{d}	36.7^{a-c}	64.9^{ab}	60.32$^{g-ı}$	1.85^{e-g}	86.44^{f-h}
Quickstan	119.5^{gh}	2126^{d-f}	621^{e-g}	13.14^{c-e}	7.21^{cd}	35.2^{d-h}	64.8^{a-c}	61.47^{b-f}	1.85^{e-g}	88.35^{d-h}
Rambo	123.3^{e-g}	1804^{h}	558^{gh}	13.37^{bc}	7.16^{cd}	36.2^{b-e}	64.5^{a-d}	60.70^{e-h}	1.86^{d-g}	87.62^{d-h}
Teanna	115.4^{ı}	1572^{ı}	387^{j}	12.36^{c-h}	9.57^{b}	35.4^{c-g}	63.8^{a-f}	61.36^{c-g}	1.88^{c-g}	89.50^{c-f}
Tornado	127.9^{a-d}	1808^{h}	486^{ı}	11.21^{ı}	7.33^{cd}	35.9^{b-f}	64.4^{a-d}	60.95^{d-h}	1.86^{d-g}	88.05^{d-h}
Trinova	126.5^{b-e}	1771^{h}	558^{gh}	12.25^{d-h}	7.30^{cd}	35.7^{b-g}	63.9^{a-e}	61.08^{c-h}	1.88^{c-g}	88.99^{d-g}
Vallivert	121.8^{f-h}	1407^{j}	392^{j}	12.57^{c-g}	8.33^{b-d}	35.3^{c-h}	63.0^{c-g}	61.38^{b-g}	1.91^{a-e}	90.67^{a-e}
Venüs	127.9^{a-d}	1884^{gh}	597^{f-h}	12.15$^{e-ı}$	7.21^{cd}	35.6^{b-g}	64.1^{a-e}	61.16^{c-h}	1.87^{c-g}	88.74^{d-g}
Zeybek-19	122.2^{f-h}	1413^{j}	478^{ı}	11.48^{hı}	7.87^{b-d}	36.0^{b-f}	63.8^{a-e}	60.84^{d-h}	1.88^{c-g}	88.68^{d-g}
Average	124.3**	2045**	612**	12.47**	7.61**	35.6**	63.7**	61.14**	1.89**	89.43**
CV	1.96	4.54	7.07	4.84	5.29	2.50	1.85	1.13	1.85	2.66

**; significant at the P≤0.01 level. There is no statistical difference between the averages shown with the same letter.

The plant heights of Italian ryegrass varieties varied between 115.4-130.9 cm. While the highest plant height of Italian ryegrass varieties was obtained in Jivet variety, the lowest plant height was obtained in Teanna variety. In the study examining the effect of biogas slurry application on biomass production and feed quality of *Lolium*

multiflorum, it was reported that Italian ryegrass plant height varied between 63.5-117.3 cm (Xu et al., 2021).

The green and dry herbage yields of Italian ryegrass varieties varied between 1407-3240 kg da^{-1} and 392-976 kg da^{-1}, respectively. While the highest green and dry herbage yields of Italian ryegrass varieties were obtained in Excellent variety, the lowest green and dry herbage yields were obtained in Vallivert variety. In a study examining the forage yield and quality response of annual ryegrass (*Lolium multiflorum*) to different water and nitrogen levels, it was reported that the dry matter yield varied between 234-1076 kg da^{-1} (Abraha et al., 2015). While in the study conducted to determine the herbage yield and quality of some Italian ryegrass (*Lolium multiflorum* Lam.) varieties in Bingöl conditions, it was reported that the green and dry herbage yields of Italian ryegrass varieties were obtained as 3377-4458 kg da^{-1} and 808-1052 kg da^{-1}, respectively (Lale and Kökten, 2020), in the study where the effects of different harvest times on the yield and some quality elements of annual ryegrass varieties were examined, it was reported that the green herbage yield of annual ryegrass varieties varied between 1890-4460 kg da^{-1} (Demiroğlu Topçu et al., 2021). In a study examining the effect of chemical fertilizer and biogas slurry on fresh biomass yield in Italian grass, it was reported that biomass yield varied between 2936-5466 kg da^{-1} (Xu et al., 2021).

The crude protein and crude ash rates of the samples of Italian ryegrass varieties varied between 11.18-14.73% and 6.57-12.43%, respectively. The highest crude protein rate of Italian ryegrass varieties was obtained in İlkadım variety, followed by Kartetra variety, which are statistically in the same group. The highest crude ash rates were found in Koga variety. On the other hand, the lowest crude protein and crude ash rates in the samples of Italian ryegrass varieties were obtained in Big boss and Jivet varieties, respectively. In the study where the effects of different harvest times on the yield and some quality elements of annual ryegrass varieties were examined, it was reported that the crude protein and crude ash rates of annual ryegrass varieties varied between 11.16-15.04% and 10.02-13.85%, respectively (Demiroğlu Topçu et al., 2021). While Abraha et al. (2015) reported that the crude protein ratio in annual ryegrass ranged between 23.55-28.58%, Xu et al. (2021) reported that the crude protein ratio in Italian ryegrass ranged between 22.71-25.06%. On the other hand, in the study conducted to determination dry matter yields and quality characteristics of annual ryegrass (*Lolium multiflorum* Lam.) genotypes, crude protein rate was obtained as 9.7-25.8% (Akça Pelen et al., 2023).

The ADF and NDF ratios of the samples of Italian ryegrass varieties varied between 32.9-37.7% and 61.6-65.4%, respectively. While the highest ADF and NDF ratios were obtained from Big boss variety; the lowest ADF rate was found in İlkadım variety, and the lowest NDF rate was found in Kartetra and Master varieties. Abraha et al. (2015) reported that the NDF rate in annual ryegrass ranged between 38.2-40.9%. On the other hand, Yavuz et al. (2017) reported that ADF and NDF rates in annual ryegrass lines were obtained as 30.6-36.5% and 46.9-54.1%, respectively, Sidhu et al. (2020) reported that the ADF and NDF rates in Italian ryegrass grown at sowing time and different nitrogen levels were obtained as 27.7-29.5% and 41.8-46.1%, respectively. While Lale and Kökten (2020) reported that the ADF and NDF rates in Italian ryegrass varieties ranged between 38.3-40.7% and 55.0-63.4%, respectively, Demiroğlu Topçu et al. (2021) reported that the ADF and NDF rates in annual ryegrass varieties ranged between 34.8-42.0% and 53.1-60.3%, respectively, Xu et al. (2021) reported that the ADF and NDF rates in Italian ryegrass ranged between 18.4-19.5% and 35.6-36.9%, respectively.

The DMD and DMI ratios and RFV values of the samples of Italian ryegrass varieties differed statistically by 1% among varieties and varied between 59.55-62.76%, 1.84-1.95% and 84.76-94.42, respectively. In a study examining the forage yield and quality response of annual ryegrass (*Lolium*

multiflorum) to different water and nitrogen levels, it was reported that in vitro dry material digestibility varied between 75.6-83.2% (Abraha et al., 2015). While in the study carried out to determine the herbage yield and quality of some Italian ryegrass (*Lolium multiflorum* Lam.) varieties in Bingöl conditions, it was reported that the DMD, DMI ratios and RFV values of Italian ryegrass varieties were obtained as 57.22-59.04%, 1.89-2.18% and 86.44-99.55, respectively (Lale and Kökten, 2020), in the study conducted to determination of forage yield and quality characteristics of annual ryegrass (*Lolium multiflorum* Lam.) lines, it was reported that the relative feed value varied between 110.7-127.3 (Demiroğlu Topçu et al., 2021). On the other hand, in the study conducted to determination dry matter yields and quality characteristics of annual ryegrass (*Lolium multiflorum* Lam.) genotypes, DMD and RFV values were obtained as 59.3-66.9% and 96-147, respectively (Akça Pelen et al., 2023)

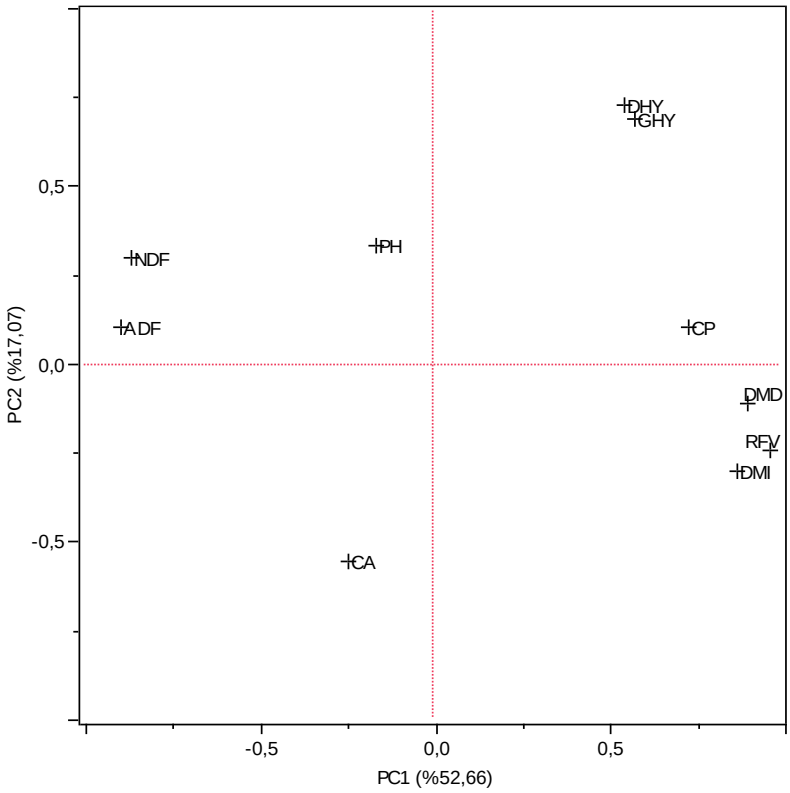

Figure 1. Principal component biplot analysis of the relationships between the examined features

Principal Component (PC) biplot analysis was performed to provide a strong demonstration of the relationships between the studied traits in Italian ryegrass herbage samples. According to the study results, PCA explained 69.73% of the total variation, while PC1 explained 52.66% and PC2 17.07% on the biplot (Figure 1). It was determined that there was a positive relationship between CP and DHY, GHY, DMD, RFV, DMI features and a negative relationship with ADF, NDF, PH and CA features.

4. Conclusions

This study was conducted to provide information about determining the herbage yield and quality of Italian ryegrass varieties grown in the Sivas climate. Italian ryegrass varieties showed significant differences in terms of herbage yield and quality. This study depicted that Excellent variety were superior in

terms of herbage yield (green and dry herbage yield) and Kartetra, Master and İlkadım varieties were superior in terms of herbage quality (low ADF, NDF rates and highest DDM, DMI and RFV).

Declaration of Author Contributions

The authors declare that they have contributed equally to the article. All authors declare that they have seen/read and approved the final version of the article ready for publication.

Declaration of Conflicts of Interest

All authors declare that there is no conflict of interest related to this article.

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