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Phenotypic characterization of rice genotypes (*Oryza sativa* L.)

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Abstract

The study was conducted to examine the phenotypic characteristics of rice (*Oryza sativa* L.) and to study their variability. The experiment was carried out in a randomized block system with 53 rice genotypes in three replications, with a plot size of 3 m2 during the 2022 vegetative year. From each genotype, 10 plants were randomly selected, and 9 phenotypic traits were examined for each of them. The influence of genotypes is highly significant for all analysed traits: plant height, stem height, panicle length, panicle weight, the number of filled grains in a panicle, the number of unfilled grains in a panicle, the weight of filled grains, the weight of unfiled grains, and the number of primary branches per panicle. The obtained results were statistically analysed by ANOVA and were tested with the LSD test, with a probability of 0.001. GN-104 showed the highest value for the panicle length (20.25 cm), the highest total number of grains (131), as well as the highest number of filled grains (106.7). GN-119 had maximum values for the panicle weight (3.79 g) and the number of filled grains (3.43), along with GN-102 (3.49). GN-152 had above average values for all positive traits but belongs to tall genotypes. GN-153 had the lowest weight per panicle (1.29 g), the lowest number of filled grains per panicle (40.47), and the lowest weight of filled grains (1.10 g), while GN-103 had the lowest number of unfilled grains per panicle. Also, the obtained results have shown that there is phenotypic variation among genotypes for these traits. This wide phenotypic variation can be used in rice breeding programs, i.e., crossing genotypes with desired traits.

***Key words**:* Plant height, Panicle weight, Filled grains, Primary branches, Paddy rice.

Introduction

Phenotypic characterization of rice genotypes is a good approach to assessing genetic and phenotypic variability among cultivars and is crucial in its assessment (Kioko et al., 2015). The height of the plant in the rice crop is of particular importance. According to the height of plants, varieties are divided into three categories: semi-dwarf (<110 cm), medium (110-130 cm), and tall (>130 cm) (International Rice Research Institute [IRRI], 2002). Tall plants are not desirable for cultivation as they are sensitive to lodging and thus will cause reduced grain yield (Shahidullah et al., 2009). In the production of rice in North Macedonia, taller rice varieties have dominated over the years (Andreevska et al., 2012; Andov et al., 2012; 2017). Despite their ability for high yield, they were not suitable for intensive production, mostly due to their susceptibility to lodging, mostly when using high doses of inorganic fertilizers (Simeonovska et al., 2019). Also, the level of lodging and the degree of complexity of harvesting is highly correlated with the height of the plant (Bhadru et al., 2011). The panicle length is one of the traits to which yield is attributed - this important trait has been regularly studied in North Macedonia (Andreevska et al., 2012; Andov et al., 2012; 2017). Rice plants with long panicles potentially have a high total grain number and high yield, as there is a positive correlation between the panicle length and the number of grains per panicle (Haryanto et al., 2008), and the 1000 grain weight (Akinwale et al., 2011).

Haryanto et al. (2008) and Hossain et al. (2005) reported that, in addition to the panicle length and the 1000 grain weight, a high total number of grains per panicle also increased rice yield. The grain yield is also determined by the number of panicles per unit area, the number of grains in a panicle, the weight and quality of the grains. In rice, there is maximum variation in the number of grains per panicle (Chauhan et al., 1989; Xu et al., 2004; Mei et al., 2006). The difference between the number of grains per panicle and the number of unfilled grains per panicle is thought to be caused by the genetic influence of each genotype. But, apart from genetic influences, environmental factors also affect the number of grains in a panicle and the number of unfilled grains in a panicle (Sadimantara et al., 2018; Espino, 2014). The denser the sowing assembly, the lower the number of grains in panicles. The number of grains per panicle is determined during panicle differentiation. Sparser sowing assembly will encourage the formation of more grains in a panicle, as well as an increased tillering. A rice plant with sparser sowing assembly will not be able to produce enough grains per panicle to compensate low panicle vigour because of the genetic limitation. The percentage of filled grains in a panicle can depend on several factors. Temperatures above 40˚C during flowering can dry out the pollen tube and cause empty, i.e., unfilled grains. Flower sterility occurs when developing pollen grains are exposed to night time temperatures ≤ 13˚C for several hours. Pollen is sensitive to low temperatures about 7-10 days after panicle initiation (Leinfelder-Miles et al., 2014). Other factors that can reduce the percentage of filled grains are excess nitrogen, rice panicle blast disease (*Pyricularia oryza*), and paddy swarming caterpillars (*Spodoptera mauritia*) that feed on developing grains. The grain weight is relatively constant; it cannot be increased to compensate for small panicles and weak production of side shoots, i.e., tillering. On the other hand, the weight of the grain can be negatively affected by the premature discharge of water from the plot before harvest. Li et al. (2010) presented the grain weight as one of the most important traits that improves variability.

The panicle structure in rice has long been a key target in rice breeding and includes the following organs: the panicle base (neck), primary and secondary branches (Ikeda et al., 2010). Each node on the main panicle axis gives rise to primary branches which in turn bear secondary branches. Primary branches may be arranged or in pairs (IRRI, 2002). Panicle branching patterns, which are mainly governed by the number of primary and secondary branches, directly determine the total number of grains. However, the improvement in grain productivity by increasing panicle branching is limited, as the panicle and the primary branches lengths are invariant. A few high-yield rice genotypes tend to have longer primary branches and produce more secondary branches, compared to standard genotypes. Therefore, the length of the panicle and the length of the primary branches affect the total number of grains and the productivity of rice (Agata et al., 2020).

The aim of this research is to examine the genetic diversity of 53 rice genotypes for several traits using phenotypic characterization. The obtained results will be used for proper conservation of these valuable genetic resources and their further introduction in the rice breeding programs.

Material and Methods

The experiment was carried out in the experimental field of the Ss. Cyril and Methodius University in Skopje, Agricultural Institute - Skopje, North Macedonia during the 2022 vegetative year. It was set up in a randomized block system with 53 rice genotypes in three replications, with a plot size of 3 m2. From each genotype, 10 plants were randomly selected, and nine phenotypic characteristics were examined for each of them (plant height - PH, stem height -

SH, panicle length - PL, panicle weight - PW, the number of filled grains per panicle - NFG, the number of unfilled grains per panicle - NUG, the weight of filled grains - WFG, the weight of unfilled grains - WUG, and the number of primary branches per panicle - NPB). The plant height was measured with a ruler from the soil surface to the tip of the panicle at full grain maturity. The panicle length was measured with a ruler from the base of the panicle to its top. The height of the stem was obtained by the difference between the height of the plant and the length of the panicle. The panicle weight was measured on a laboratory analytical balance after the harvesting season, after several weeks of moisture stabilization at room temperature tin the laboratory. The number of primary branches in a panicle was determined by counting them. In conducting the field experiment, standard agricultural techniques were applied. To observe differences in the analysed traits between the genotypes included in this research, as well as their relationship, the obtained results were processed statistically by using the analysis of variance and tested with the LSD test, with a probability of 0.001.

Results and Discussion

The analysis of variance for the phenotypic traits examined in the rice genotypes is shown in Table 1. It can be noted that the influence of genotypes is highly significant for all 9 tested traits: the plant height, the stem height, the panicle length, the panicle weight, the number of filled grains per panicle, the number of unfilled grains per panicle, the weight of filled grains, the weight of filled grains, and the number of primary branches per panicle. This indicates that there is phenotypic variation among the genotypes for these traits.

Tab. 1 Analysis of variance of the traits studied in 53 rice genotypes

F	Df	SH	PL	PH	PW	NFG	NUG	WFG	WUG	NPB
R	2	57	1.832	76.2	0.3875	211.9	68.87	0.2981	0.0006	2.360
G	52	659^{*}	14.648^{*}	813.0^{*}	1.1585^{*}	785.7^{*}	148.29^{*}	1.0477^{*}	0.0258^{*}	7.772^{*}
E	104	20.9	0.804	26.4	0.1702	111.0	24.02	0.1394	0.0041	1.599

F - Factors, R - Repetitions, G - Genotypes, E - Error, Df - Degrees of freedom, *shows significance at the 0.001 level

The average values of the 53 rice genotypes examined are presented in Table 2. From the obtained results, the height of the plants ranged from 66 cm (GN-122) to 142 cm (GN-152). According to the IRRI categorization, 44 rice genotypes examined in this paper were semi-dwarf (66-109 cm), eight genotypes were medium height (112-122 cm), and one was a tall genotype (142 cm). The results for the height of the semi-dwarf genotypes agree with those investigated by Mosaad (2012) and Castro et al. (2003), while Javed et al. (2015) obtained similar results for the height of tall genotypes. The length of panicles in the studied genotypes ranged from 11 cm (GN-138) to 20.25 cm (GN-104) and is in agreement with the studies of Javed et al. (2015). Panicle weight values ranged from 1.29 g (GN-153) to 3.79 g (GN-119).

The average total number of grains per panicle was 87. Espino (2014) obtained similar results for California rice varieties, which typically produced 70-100 grains per panicle. The number of filled grains in a panicle ranged from 40.47 (GN-153) to 106.70 (GN-104), and the weight of filled grains in a panicle from 1.10 g (GN-153) to 3.49 (GN-102). The percentage of unfilled grains varied between the genotypes and ranged from 0.6% (GN-128) to 3.8% (GN-145), while the weight of unfilled grains per panicle ranged from 0.15 (GN-103 to 0.70 (GN-121). The number of primary branches also affects the number and the total weight of grains in a panicle. The average number of primary branches per panicle in all studied genotypes was 9.89.

Tab. 2 Mean performance of 53 rice genotypes based on different phenotypic traits

Genotypes	SH (cm)	PL (cm)	PH (cm)	PW (g)	NFG	NUG	WFG (g)	WUG (g)	NPB
GN-101	87.77	16.37	104	3.38	71.27	18.43	3.03	0.35	10.00
GN-102	89.63	16.70	106	3.73	89.70	11.97	3.49	0.25	10.27
GN-103	81.83	15.63	97	1.99	58.90	8.53	1.88	0.15	10.43
GN-104	94.53	20.25	115	3.44	106.70	24.03	3.11	0.33	11.47
GN-105	91.13	17.93	109	3.33	83.17	24.87	2.97	0.36	12.43
GN-106	94.50	18.67	113	3.29	82.37	17.10	2.96	0.33	11.90
GN-107	101.10	16.33	117	3.04	90.87	12.53	2.72	0.32	9.40
GN-108	95.93	16.53	112	2.90	93.30	10.43	2.58	0.32	9.50
GN-109	90.70	16.03	107	3.29	71.90	13.97	2.94	0.35	8.87
GN-110	82.23	17.33	100	3.30	79.00	16.03	2.97	0.36	10.53
GN-111	85.70	16.43	102	2.81	72.80	12.07	2.58	0.23	8.97
GN-112	88.77	16.83	106	3.02	73.00	19.30	2.75	0.27	9.13
GN-113	83.87	15.55	99	2.98	81.50	10.60	2.76	0.21	10.47
GN-114	94.47	17.63	112	2.44	63.53	13.10	2.21	0.23	8.37
GN-115	60.88	14.57	75	1.84	59.33	20.57	1.60	0.24	8.67
GN-116	96.17	16.07	112	2.81	88.10	24.80	2.47	0.33	10.70
GN-117	67.27	11.88	79	1.88	65.20	28.03	1.55	0.33	10.13
GN-118	91.40	17.63	109	2.65	81.30	13.57	2.34	0.36	10.20
GN-119	98.80	17.60	116	3.79	105.67	24.37	3.43	0.36	11.23
GN-120	80.27	14.60	95	3.11	79.23	20.10	2.84	0.27	11.13
GN-121	79.93	14.43	94	2.37	79.10	28.10	2.00	0.70	11.50
GN-122	51.73	14.13	66	1.61	49.80	21.80	1.39	0.22	12.63

GN-123	71.20	11.80	83	2.23	64.30	9.43	2.02	0.21	9.17
GN-124	93.23	16.03	109	2.75	69.33	7.30	2.49	0.26	9.63
GN-125	91.10	15.93	107	3.07	71.67	15.17	2.69	0.38	11.77
GN-126	90.00	15.60	106	2.65	63.60	10.70	2.36	0.28	8.40
GN-127	73.80	14.80	89	2.79	66.30	11.93	2.39	0.47	9.27
GN128	66.10	11.97	78	1.96	45.20	5.00	1.72	0.25	7.07
GN-129	74.67	14.73	89	2.35	64.57	11.87	2.04	0.31	9.13
GN-130	72.10	11.93	84	2.75	81.10	18.53	2.42	0.33	10.40
GN-131	82.53	13.83	96	1.94	47.30	21.50	1.70	0.24	7.67
GN-132	77.83	14.63	92	1.94	48.73	22.60	1.65	0.29	9.07
GN-133	71.07	11.13	82	2.08	52.63	15.67	1.81	0.27	8.37
GN-134	72.70	11.33	84	2.32	71.77	12.50	2.13	0.19	8.73
GN-135	63.20	14.52	78	3.34	88.13	32.63	2.87	0.47	13.37
GN-136	80.03	13.45	93	1.99	60.17	12.67	1.81	0.18	9.03
GN-137	75.48	11.37	87	2.09	66.87	14.73	1.93	0.16	9.90
GN-138	70.80	11.00	82	2.12	71.07	16.87	1.95	0.17	11.20
GN-139	53.85	12.25	66	1.62	51.73	30.07	1.37	0.25	9.90
GN-140	78.57	14.18	93	2.93	67.83	15.33	2.57	0.36	9.03
GN-141	74.43	12.98	87	2.71	77.83	22.30	2.32	0.39	10.50
GN-142	61.52	16.32	78	2.65	65.70	19.13	2.26	0.39	8.57
GN-143	93.47	15.00	108	2.46	58.83	15.90	2.16	0.30	8.67
GN-144	66.23	14.10	80	1.64	36.70	13.17	1.36	0.29	7.40
GN-145	55.03	12.10	67	1.62	50.43	34.27	1.27	0.35	9.90
GN-146	56.13	12.28	68	2.06	79.70	10.23	1.84	0.22	10.50
GN-147	105.40	17.00	122	2.78	47.40	8.43	1.82	0.25	6.97
GN-148	92.53	15.63	108	3.22	82.73	13.97	2.92	0.30	9.50
GN-149	64.57	16.48	81	2.89	68.47	8.50	2.50	0.40	8.37
GN-150	63.67	13.40	77	2.96	83.37	11.87	2.64	0.32	11.73
GN-151	64.03	14.08	78	1.70	49.53	33.93	1.41	0.29	10.00
GN-152	122.87	19.12	142	3.41	100.00	14.73	3.09	0.32	15.33
GN-153	90.50	15.32	106	1.29	40.47	20.20	1.10	0.19	7.60
CV%	0.19	0.15	0.17	0.24	0.23	0.42	0.26	0.31	0.16
Min	51.73	11.00	66.00	1.29	40.47	5.00	1.10	0.15	6.97
Max	122.87	20.25	142.00	3.79	106.7	34.27	3.49	0.70	15.33
Mean	80.18	14.94	95.29	2.58	70.15	17.06	2.27	0.30	9.89
SD	14.90	2.23	16.44	0.62	16.34	7.10	0.59	0.09	1.62
LSD (0.05)	1.03	0.20	1.16	0.09	2.37	1.10	0.08	0.01	0.28

SH - stem height, PL - panicle length, PH - plant height, PW - panicle weight, NFG - number of filled grains per panicle, NUG - number of unfilled grains per panicle, WFG - weight of filled grains, WUG - weight of unfilled grains, and NPB - number of primary branches per panicle. CV% - Coefficient of variation, Min - minimum, Max - maximum, SD - standard deviation.

Conclusion

From the obtained results it can be concluded that there are significant variations for all investigated traits among the genotypes. GN-119 and GN-102 had the highest values for the panicle weight and the filled grain weight. GN-104 was the genotype with the longest panicle and the highest total number of grains. GN-128 had the lowest number of unfilled grains per panicle, while GN-103, GN-137, and GN-138 had the lowest weight of unfilled grains. GN-152 had values above the average for all positive traits except for the high plant height which is generally a negative trait in rice production. The phenotypic analysis performed in this study can serve as a basis for additional research included in rice selection programs, i.e., hybridization of genotypes with desired traits.

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Фенотипска карактеризација различитих генотипова пиринча (*Oryza sativa* L.)

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Сажетак

Студија је спроведена ради испитивања фенотипских карактеристика пиринча (*Oryza sativa* L.) и проучавања њихове варијабилности. Експеримент је изведен у рандомизованом блок систему са 53 генотипа пиринча у три понављања, са површином од 3 m^2 током вегетативне 2022. године. Из сваког генотипа насумично је одабрано 10 биљака, а за сваку је испитано 9 фенотипских особина. Утицај генотипова је веома значајан за све анализиране особине: висину биљке, висину стабљике, дужину метлице, масу метлице, број напуњених зрна у метлици, број неиспуњених зрна у метлици, масу напуњених зрна, масу непуних зрна и број примарних грана по метлици. Добијени резултати су статистички анализирани методом ANOVA и тестирани LSD тестом, са вероватноћом од 0,001. ГН-104 је показао највећу вредност дужине метлице (20,25 cm), највећи укупан број зрна (131), као и највећи број напуњених зрна (106,7). ГН-119 има максималне вредности за тежину метлице (3,79 g) и број напуњених зрна (3,43), заједно са ГН-102 (3,49). ГН-152 има изнадпросечне вредности за све позитивне особине, али припада високим генотиповима. ГН-153 има најмању тежину по метлици (1,29 g), најмањи број напуњених зрна по метлици (40,47) и најмању тежину напуњених зрна (1,10 g), док ГН-103 има најмањи број ненапуњених зрна по метлици. Такође, добијени резултати показују да постоји фенотипска варијација међу генотиповима за ове особине. Широка фенотипска варијација се може користити у програмима оплемењивања пиринча, односно укрштања генотипова са жељеним особинама.

Кључне ријечи: висина биљака, маса метлице, број напуњених зрна у метлици, примарне гране, љуштени пиринач.

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