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QUALITY PARAMETERS OF WHEAT GENOTYPES GROWN IN DIFFERENT LOCATIONS

PARAMETRI KVALITETA ZRNA GENOTIPOVA PŠENICE GAJENIH NA RAZLIČITIM LOKACIJAMA

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ABSTRACT

Wheat is a staple food for many nations worldwide, providing essential nutrients and energy. Five local wheat cultivars were grown at four different locations in Serbia to investigate variations in grain quality. Standard laboratory procedures were used to analyze grain test weight, chemical composition, and gluten content of whole-wheat flour. Significant differences in chemical composition, gluten content, and test weight were noted among the genotypes and across locations. The test weight of all samples ranged from 71.20 to 80.76 kg/hl, making them suitable for industrial purposes (≥73 kg/hl). However, only 65% of the samples met the quality requirement for human consumption (≥76 kg/hl), as specified by Serbian regulations on the quality of grain, mill, bakery products, and pasta. Gluten content varied from 20.9% to 43.8%. The highest starch content was found in the cultivar Aurelija from Donja Trepča (67.46% d.m.), while the highest protein content (16.04% d.m.) was observed in the cultivar Osatka from Zemun Polje. The findings indicate that both genotype and location (i.e., environment) have a considerable effect on grain quality. Nevertheless, these quality parameters are considered high quality under Serbian regulations for cereal grains and products.

***Keywords**: wheat; chemical composition; quality parameters*

REZIME

Pšenica predstavlja osnovnu namirnicu u ishrani mnogih naroda širom sveta, obezbeđujući esencijalne hranljive materije i energiju. Pet lokalnih sorti pšenice uzgajano je na četiri različite lokacije u Srbiji kako bi se ispitale varijacije u kvalitetu zrna. Standardne laboratorijske procedure su korišćene za analizu hektolitarske mase zrna, hemijskog sastava i sadržaja glutena u integralnom pšeničnom brašnu. Rezultati ukazuju da su na parameter kvaliteta genotipa Zemunska Rosa najviše uticali uslovi sredine prisutni na oglednim lokacijama posebno na hektolitarsku masu, sadržaj proteina i ulja. Hektolitarska masa uzoraka kretala se od 71,20 do 80,76 kg/hl, što ih čini pogodnim za industrijsku namenu (≥73 kg/hl). Međutim, samo 65% uzoraka ispunjavalo je zahteve kvaliteta za ljudsku ishranu (≥76 kg/hl), kako je navedeno u srpskim propisima o kvalitetu žitarica, mlinskih, pekarskih proizvoda i testenina. Sadržaj glutena varirao je od 20,9% do 43,8%. Najveći sadržaj skroba utvrđen je kod sorte Aurelija iz Donje Trepče (67,46% s.m.), dok je najviši sadržaj proteina (16,04% s.m.) uočen kod sorte Osatka iz Zemun Polja. Rezultati ukazuju da i genotip i lokacija (tj. okolina) imaju značajan uticaj na kvalitet zrna. Ipak, ovi parametri kvaliteta se smatraju visokokvalitetnim prema srpskim propisima za žitarice i proizvode. Sorta Osatka pokazala je značajne varijacije u sadržaju proteina i ulja, dok je Aurelija pokazala najvišu varijabilnost u sadržaju glutena po lokacijama. Ovi rezultati ukazuju na značaj istraživanja vezanih za uticaj lokacije na parameter kvaliteta zrna pšenice, koja mogu biti od ključnog značaja za razvoj programa oplemenjivanja strnih žita.

***Ključne reči**: pšenica, hemijski sastav; parametric kvaliteta*

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the oldest and most widely grown food sources, highly significant to the world's population (*Gong et al., 2019*). The majority of wheat-based products are made of refined flour, which lacks vital nutrients lost during milling when the bran and germ are removed (*Bhat et al., 2020*). However, excessive consumption of refined grain meals is linked to a higher risk of obesity, type 2 diabetes, coronary atherosclerosis, chronic cardiovascular disease, and colon cancer, according to epidemiological research (*Cheng et al., 2022*). Two essential macromolecular elements that contribute to the unique functional properties of refined wheat flour, mainly for food processing, are protein and starch (*Ee et al., 2020*). According to *Elvers and Ullman (2017)* and *Žilić et al. (2011)*, the average protein and starch contents of wheat grains range from 7% to 15% and 54% to 72%, respectively. Nutrients included in whole wheat include minerals, dietary fiber, B vitamins, and phytochemicals such flavonoids, carotenoids, tocopherols, and phenolic acids, all of which have potential health benefits (*Gong et al., 2019*). Dietary fiber, proteins, and bioactive phytochemicals in whole grain flours offer potential long-term health benefits. In developing regions, cereals are a dietary staple and main energy source, yet milling processes often diminish their micronutrient content by removing the nutrient-rich germ and bran (*Nikolić et al., 2022*). The aleurone layer, which has the highest antioxidant activity, contains the majority of these chemicals, followed by bran and germ. Because fiber binds most of the bioactive ingredients in bran, they can withstand digestion in the gastrointestinal tract and make it into the colon undigested, where they produce an antioxidant environment (*Nikolić et al., 2023*).

Whole-grain wheat flour is gaining in popularity as a food ingredient that contributes a significant amount of calories and protein to the daily diets of many consumers worldwide. Wheat breeding programs, production practices, and marketing initiatives all acknowledge the significance of wheat grain quality (*Kandić et al., 2023*). Test weight serves as an indicator of grain filling, kernel maturity, and potential starch accumulation, for overall grain quality (*Hossain et al., 2003*). The protein content is a crucial technological parameter of cereal grains, influencing their end use based on the level of gluten proteins, which in turn affects the quality of cereal-based products (*Kandić et al., 2023*). Gluten is the primary storage protein found in wheat grains. It represents a complex mixture of related yet different proteins, primarily gliadin and glutenin (*Biesiekierski*, *2017*). Gluten, measured as either wet or dry gluten, is a significant factor that determines the baking quality of cereals by affecting water absorption capacity, cohesiveness, viscosity, and elasticity of dough (*Wieser, 2007*). The interactions between the two main macromolecular components, protein and starch, have a significant impact on the specific functional characteristics of wheat flour for food production, including bread loaf volume, starch pasting, and rate of starch digestion (*Žilić et al., 2011*). Furthermore, understanding the relative contributions of environment (E), genotype (G), and the interaction between genotype and environment (GxE) to the quality of wheat allows breeding programs to select more efficiently. Consequently, soil and biological aspects of the climate (temperature, precipitation, humidity, solar radiation, and carbon dioxide content), commonly referred to as abiotic environmental elements, have an impact on conditions (E) (Roostaei et al., 2021). A variety of biological factors, including quantitative traits, physiological indicators, morphological traits, and stress tolerance, combine to form wheat's grain yield, which is an integral quantity (lo Valvo et al., 2018; Garcia et al., 2019; Senapati et al., 2020). Diseases and pests are examples of biotic variables that contribute to the complex picture of interactions in an actual environment (Spanic et al., 2020). From a breeding perspective, it can be assumed that when good agricultural techniques (fertilization, plant protection, irrigation) are used, only environmental and genetic elements remain for research in the field of interactions (Tsenov et al., 2022). This knowledge helps to separate more uniform grain kernels that better meet consumer demands (*Williams et al., 2008*).

This research aimed to investigate the quality parameters of five local wheat genotypes cultivated in four different locations in Serbia, seeking to deepen our understanding of their variability influenced by similar geographical settings. However, the article does not provide details or comments on the specific environmental conditions due to the lack of data. By analyzing the result of the quality parameters of grains collected from these diverse locations, we aimed to identify which genotypes demonstrate the optimal quality parameters, ultimately enhancing the overall yield and quality of wheat in the region.

MATERIAL AND METHOD

Five winter bread wheat genotypes (*Triticum aestivum* L.), namely four cultivars bred at the Maize Research Institute, Zemun Polje, Osatka, Zemunska rosa, Aurelija, and ZP Sara, and one cultivar marked as Genotype 1 from a different producer, with were used in this study. The investigated genotypes were cultivated during the 2024/2025 growing season in a randomized complete block design (RCB) with two replications. Each plot (5 rows, 1.0 m long) was sown with 250 seeds, with rows and plots spaced 0.2 m apart. The sowing took place in October at four locations in Serbia: Donja Trepča (municipality of Čačak, Moravica District, 43.9136°N 20.4708°E); Sefkerin (Opovo municipality, South Banat District, Vojvodina, 45°00′10″N 20°28′35″E), Zemun Polje (Zemun municipality, Belgrade, 44°52′N 20°19′E), and Klenje (Bogatić municipality, Mačva District, 44°50′N 19°29′E). In order to keep the plots free of weeds and diseases and to provide the plants with sufficient nutrients, standard cultivation techniques were applied.

Test weight of the wheat grain samples was determined on a Schopper chondrometer in five consecutive measurements, and the results were expressed in kg/hl as the average value calculated at 13% moisture (*SRPS EN ISO 7971-3:2019*). To prepare fine samples for the determination of chemical composition, whole-wheat flour was ground in a laboratory mill (Perten Mill 120 CE; Perten Instruments, Hägersten, Sweden) with a mesh size of 0.5 mm.

The dry matter content of the samples was determined after standard drying method at 105 ˚C in a drying oven (Memmert UF 55; Memmert GmbH + Co. KG) to constant mass (AOAC, 1990). The starch content was analyzed according to the method introduced by Ewers (*ISO 10520:1997*) on a polarimeter (UniPol L 2020; Schmidt + Haensch GmbH & Co., Berlin, Germany). The protein content of the wheat samples was obtained by the Kjeldahl method performed on the BÜCHI Kjeldahl System (AutoKjeldahl distillation unit K-350 and speed digester K-439; BÜCHI Labortechnik, Flawil, Switzerland), with total nitrogen multiplied by factor 5.7 used for wheat and wheat flour (*AOAC, 1990*). The oil content was determined according to the Soxhlet method AOAC 920.39 (*AOAC, 2000*) using FatExtractor E-500 (Büchi Labortechnik,). Weende method adjusted for Fibretec Systems (Foss, Hilleroed, Denmark) was used to determine the cellulose content (*ISO 5498:1981*).

Gluten was extracted through thorough washing of the dough using a 2% NaCl solution, followed by rinsing with tap water (*AACC, 2000*). Gluten was air-dried in a ventilated oven (Memmert UF 55; Memmert GmbH + Co. KG) at ambient temperature (maximum 25 °C) for roughly 10 hours. The wet gluten content was expressed as a percentage of the initially weighed flour calculated on wet basis (w.b.).

The chemical analyses were performed in duplicates, and the results were expressed as mass percentage ± standard deviation, calculated on dry mass basis. Statistical analyses were performed using Minitab19 Statistical Software. The one-way ANOVA analysis of variance with Tukey's test was conducted to obtain differences between chemical components off all genotypes per location, and each genotype on various locations, respectively. Differences between the means with probability $p < 0.05$ were accepted as statistically significant.

RESULTS AND DISCUSSION

Test weight is a measure of grain density, indicating how much a specific volume of grain weighs. Test weight, also referred to as hectoliter weight or volumetric mass, represents the mass per unit volume, which reflects the density of the grain mass. Test weight of wheat is an important quality indicator, representing the weight of one hectoliter (100 liters) of wheat grain, calculated to a standard of 13% moisture, and usually ranges from 60 to 84 kg/hl (or 600-840 kg/m³) for quality wheat (*Dündar et al., 2025; Ćirković, 2025*).

The determined values in the samples of the investigated wheat genotypes on different locations in Serbia are shown in Figure 1.

The lowest test weight was determined for the Zemunska Rosa variety at the Zemun Polje location (71.20 kg/hl), and the highest was determined for the Zemunska Rosa variety at the Klenje location (80.76 kg/hl) (Fig. 1.). A higher test weight indicates better physical characteristics of the grain, greater fullness and higher flour yield, while a lower one is associated with grains of low moisture, poorer quality, or higher impurities. However, the unclear trends in test weight in relation to starch and protein content may stem from various factors. *N*umerous factors affect test weight, including kernel size and shape, grain filling, moisture content, quantity and kind of extraneous materials, surface area condition, and meteorological conditions (Lakić-Karalić et al., 2021; Gaines et al., 1997).

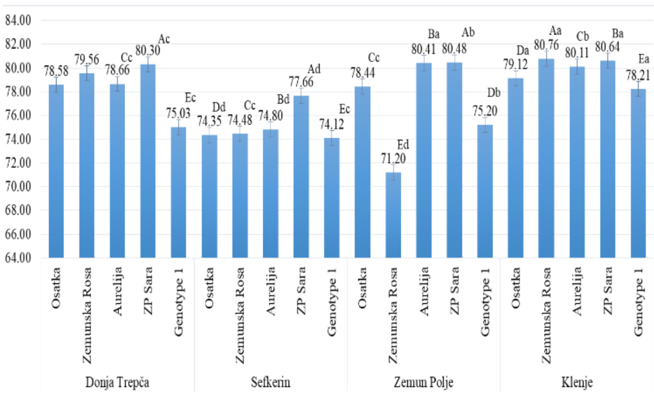

Fig. 1. Test weights of the investigated wheat grain samples, by location (kg/hl)

(Values are means of two determinations ± standard deviation. Means followed by the same letter within the same column are not significantly different (p < 0.05). Uppercase letters signify differences between genotypes at the same location, while lowercase letters signify differences in each genotype's test weights at various locations.)

Certain research studies have indicated a lack of robust correlation between test weight and certain quality attributes, which accounts for the infrequent utilization of test weight as a method (Žeželj, 1995).

According to the Serbian regulation, a test weight equal to or higher than 72 kg/hl is considered adequate for industrial purposes, while values from 76 kg/hl and higher are considered optimal for food, *i.e.,* human consumption (Službeni glasnik, 2018). The chemical composition of the analyzed whole-wheat flour samples is represented in Table 1.

Table 1. Chemical composition of the investigated wheat samples, by location

Location	Genotype	Dry matter (%)	Starch (% d.m.)	Protein (% d.m.)	Oil (% d.m.)	Cellulose (% d.m.)
Donja Trepča	Osatka	91.22	64.33 ± 0.47^{Ba}	11.96 ± 0.10^{Bd}	1.84 ± 0.01^{Ba}	3.07 ± 0.50^{Aa}
	Zemunska Rosa	90.88	66.79 ± 0.23^{Aa}	11.55 ± 0.04^{Cd}	1.79 ± 0.02^{Bbc}	3.23 ± 0.51^{Aa}
	Aurelija	91.36	67.46 ± 0.46^{Aa}	11.31 ± 0.00^{Cd}	1.73 ± 0.05^{Ba}	3.13 ± 0.27^{Aa}
	ZP Sara	91.14	64.51 ± 0.11^{Bab}	13.54 ± 0.06^{Abc}	1.53 ± 0.05^{Cb}	2.74 ± 0.02^{Ab}
	Genotype 1	91.65	63.47 ± 0.18^{Bab}	13.23 ± 0.13^{Ab}	2.16 ± 0.03^{Aa}	3.14 ± 0.09^{Aa}
	CV	0.32	2.47	7.56	12.42	6.99
Sefkerin	Osatka	91.89	59.85 ± 0.06^{Cc}	15.01 ± 0.10^{Ab}	1.96 ± 0.03^{Aba}	3.10 ± 0.14^{Aa}
	Zemunska Rosa	91.99	62.53 ± 0.10^{Bd}	14.34 ± 0.03^{Ba}	1.96 ± 0.01^{Aba}	3.15 ± 0.38^{Aa}
	Aurelija	91.89	62.91 ± 0.16^{Bd}	13.49 ± 0.06^{BCb}	1.76 ± 0.03^{Ba}	3.35 ± 0.04^{Aa}
	ZP Sara	91.87	64.81 ± 0.28^{Aa}	13.24 ± 0.24^{Cc}	1.85 ± 0.11^{Ba}	3.09 ± 0.02^{Aa}
	Genotype 1	91.82	61.86 ± 0.49^{Bb}	13.48 ± 0.08^{BCb}	2.07 ± 0.01^{Aab}	3.10 ± 0.08^{Aa}
	CV	0.07	2.88	5.34	6.17	3.48
Zemun Polje	Osatka	91.80	60.19 ± 0.18^{Bc}	16.04 ± 0.04^{Aa}	1.86 ± 0.01^{Ba}	2.98 ± 0.22^{Aa}
	Zemunska Rosa	91.41	65.28 ± 0.02^{Bd}	12.37 ± 0.11^{Ec}	1.85 ± 0.02^{Bb}	2.98 ± 0.28^{Aa}
	Aurelija	91.31	64.10 ± 0.18^{Cc}	13.72 ± 0.03^{Da}	1.54 ± 0.00^{Da}	3.13 ± 0.01^{Aa}
	ZP Sara	91.38	61.60 ± 0.42^{Ac}	15.38 ± 0.11^{Ba}	1.65 ± 0.06^{Cab}	2.96 ± 0.05^{Aa}
	Genotype 1	91.83	61.26 ± 0.06^{Cb}	14.04 ± 0.02^{Ca}	1.98 ± 0.01^{Aab}	3.08 ± 0.14^{Aa}
	CV	0.27	3.39	10.08	9.98	2.47
Klenje	Osatka	91.15	63.12 ± 0.13^{Cb}	13.48 ± 0.01^{Bc}	1.51 ± 0.08^{Bb}	3.34 ± 0.10^{Aa}
	Zemunska Rosa	90.46	64.54 ± 0.21^{Bc}	12.93 ± 0.08^{Cb}	1.77 ± 0.02^{ABc}	3.04 ± 0.17^{Aa}
	Aurelija	90.64	65.86 ± 0.13^{Ab}	12.53 ± 0.04^{Dc}	1.59 ± 0.12^{ABa}	2.98 ± 0.16^{Aa}
	ZP Sara	90.84	63.55 ± 0.33^{Cb}	14.09 ± 0.02^{Ab}	1.58 ± 0.06^{ABab}	3.10 ± 0.08^{Aa}
	Genotype 1	91.14	63.37 ± 0.07^{Ca}	12.65 ± 0.13^{CDc}	1.86 ± 0.12^{Ab}	3.36 ± 0.13^{Aa}
	CV	0.33	1.76	4.93	8.82	5.54

CV – coefficient of variation (%); Values are means of two determinations ± standard deviation. Means followed by the same letter within the same column are not significantly different (p < 0.05). Uppercase letters signify differences between genotypes at the same location, while lowercase letters signify differences in each genotype's properties at varying locations.

The results presented in Table 1 show that the starch content ranged from 59.85% d.m. (Osatka, Sefkerin) to 67.46% d.m. (Aurelija, Donja Trepča), the oil content from 1.51% (Osatka, Klenje) to 2.16% (Genotype 1, Donja Trepča), the protein content from 16.04% (Osatka, Zemun Polje) to 11.31% (Aurelija, Donja Trepča), the cellulose content from 2.74% (ZP Sara, Donja Trepča) to 3.36% (Genotype 1, Klenje). The cellulose content analysis indicated no significant differences among genotypes and locations, except for ZP Sara, which exhibited significantly lower cellulose content compared to other genotypes at the Donja Trepča location (Table 1). The cellulose content range was in accordance with findings from a HEALTHGRAIN EU FP6 programme (2005–2010), which reported that the average cellulose content of whole-grain flour from 129 winter wheat genotypes ranged from 1.67 to 3.05% (Andersson et al., 2013).

The obtained values of wet gluten extracted from wheat dough of the investigated wheat samples are shown in Figure 2. The content of wet gluten varied from 20.9% (Aurelija, Donja Trepča) to 43.8% (ZP Sara, Zemun Polje). The results are in accordance with previous findings reported by Žilić et al. (2011).

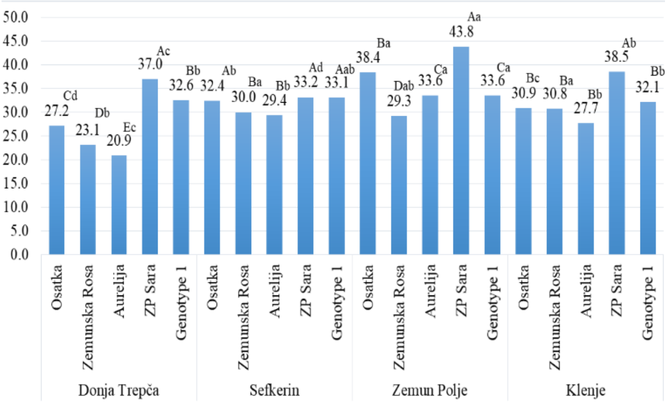

Fig. 2. Wet gluten content of the investigated wheat flour samples, by location (%w.b.)

(Values are means of two determinations ± standard deviation. Means followed by the same letter within the same column are not significantly different (p < 0.05). Uppercase letters signify differences between genotypes at the same location, while lowercase letters signify differences in each genotype's wet gluten content at various locations.)

Wet wheat gluten consists of a protein network that gives elasticity to the dough, retains gas during rising and allows the dough to hold its shape, is produced by separating it from wheat flour (usually from *Triticum aestivum*), , Gluten content is crucial for the baking industry (bread, pastries) and is also important in cosmetics (*Janković et al., 2015*). According to the International Association for Cereal Science and Technology (ICC, 2018), wet gluten is a viscoelastic, rubbery material consisting of hydrated proteins—gliadin and glutenin—extracted by washing starch from wheat flour dough. It represents the elastic structure of dough that retains gas during fermentation, directly influencing bread volume. In general, gliadin is thought to regulate the dough's viscosity, while glutenin regulates its elasticity or strength (Žilić et al., 2011). In wet gluten, the water content is about 56%, but hydration is not a constant value and changes depending on numerous factors. Washed and dried gluten consists of 80-90% protein, and the remaining 10-20% is made up of starch, lipids, sugar, cellulose, etc. The gluten content depends on the genetic basis of the variety, as well as growing conditions (*Dahunsi, 2015*).

The quality parameter variations between locations for individual wheat genotypes are presented in Table 2.

Table 2. Quality parameter variations between locations for individual wheat genotypes

Genotype	Statistical trait	Test weight (kg/hl)	Dry matter (%)	Starch (% d.m.)	Protein (% d.m.)	Oil (% d.m.)	Cellulose (% d.m.)	Wet gluten (% w.b.)
Osatka	Mean	77.62	91.52	61.87	14.12	1.79	3.12	32.23
	SD	2.20	0.38	2.20	1.78	0.20	0.15	4.66
	CV	2.84	0.42	3.56	12.64	10.91	4.92	14.46
Zemunska Rosa	Mean	76.50	91.19	64.79	12.80	1.84	3.10	28.30
	SD	4.46	0.66	1.77	1.17	0.09	0.11	3.52
	CV	5.83	0.73	2.73	9.17	4.63	3.60	12.44
Aurelija	Mean	78.50	91.30	65.08	12.76	1.66	3.15	27.90
	SD	2.58	0.51	2.00	1.10	0.11	0.15	5.28
	CV	3.29	0.56	3.07	8.60	6.44	4.84	18.94
ZP Sara	Mean	79.77	91.31	63.62	14.06	1.65	2.97	38.13
	SD	1.41	0.44	1.45	0.95	0.14	0.17	4.39
	CV	1.77	0.48	2.28	6.73	8.51	5.64	11.52
Genotype 1	Mean	75.64	91.61	62.49	13.35	2.02	3.17	32.85
	SD	1.78	0.32	1.10	0.58	0.13	0.13	0.65
	CV	2.35	0.35	1.76	4.32	6.35	4.07	1.96

SD – standard deviation; CV – coefficient of variation (%); Values are means of three determinations ± standard deviation. Means followed by the same letter within the same column are not significantly different (p < 0.05).

Test weight of the genotype Zemunska Rosa varied the most among locations (CV=5.83), indicating that the environmental factors of the location influenced this parameter the most. Furthermore, variations in Osatka cultivars' protein and oil content (CV - 12.64 and 10.91%, respectively) were highly statistically significant among locations. The Aurelia cultivar exhibited the highest coefficient of variation (18.94%) for gluten content, indicating that environmental conditions significantly affected this quality parameter.

CONCLUSION

The examination of the Zemunska Rosa genotype revealed a compelling interplay between environmental factors and key agricultural metrics, particularly test weight, which displays considerable variability across different locations. This variability underscores the importance of growing conditions in determining the overall quality of crops. Furthermore, the Osatka cultivar demonstrated notable fluctuations in protein and oil content, emphasizing that these traits are also shaped by external influences. Among the cultivars studied, Aurelia stands out with an impressive variation in gluten content of 18.94%, further illustrating how environmental conditions can dramatically affect nutritional quality. Collectively, these findings highlight the critical need for crop breeders, farmers, and agronomists to consider local environmental factors when assessing crop performance and quality, ultimately guiding more tailored cultivation practices to optimize yields and enhance food security.

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