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Quantitative and Qualitative Potential of Peanuts Produced in Northwestern Paraná, Brazil

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Abstract

The quantification and qualification of the productive potential of peanuts allow for the differentiation of cultivars and identification of the most productive ones at regional levels. This study aimed to evaluate the productivity and grain quality of peanut cultivars and genotypes cultivated in the northwest region of Paraná. The treatments were arranged in a randomized complete block design consisting of four cultivars and four genotypes, with four replications, in plots of 3.6x3.0 m composed of four rows spaced at 0.9 m. Plants were evaluated pre-harvest, at harvest, and post-harvest to characterize their productive potential. Data were subjected to analysis of variance using the F-test, and means were compared using the Scott-Knott test ($p \geq 0.05$). There were significant differences among treatments for the variables analyzed. Productivity ranged from 3225.45 kg ha^{-1} to 5129.31 kg ha^{-1}. Genotypes 2173 OL and 2091 OL, and cultivars BRS 425 OL and BRS 427 OL showed the best productive performance. Cultivar BRS 421 OL and genotype 2173 OL exhibited lower severity of early leaf spot. Under the edaphoclimatic conditions of management and cultivation, the genetic origin influenced the productive potential of the tested lines.

Keywords: *Arachis hypogaea* L., biophysical parameters, grain quality, productivity

1. Introduction

The economic viability of peanut cultivation in the Brazilian agribusiness sector is notable, as evidenced by its significant commercial and social economic impact in producing regions, as well as the generation of direct and indirect employment throughout the production chain. Due to its ability to fix atmospheric nitrogen (Desmae et al., 2018), increase water capacity and availability, reduce incidence and severity of peanut ring spot virus (Betiol et al., 2023), and benefit various agronomic parameters (PANG et al., 2021; TANG et al., 2021), as well as soil conservation (Carrega, Nepomuceno & Alves, 2022), peanuts have potential for use in crop rotation systems, akin to practices seen in sugarcane reforms. In the state of Paraná, economic competitiveness with other crops has reduced peanut cultivation area, but there have been increases in productivity (Pereira et al., 2023; Silva et al., 2021). Among the main challenges in peanut cultivation are labor costs and the high cost of machinery, which impact the success of the production system. Research for developing new cultivars, especially regionally, is a continuous and fundamental process for the success of the peanut production chain (Heuert et al., 2020). Through genetic improvement programs, production mechanization, and demand for higher yields, dwarf cultivars are responsive to management, especially nutritional (Nakagawa, Rosolem, 2011), and in crop rotation systems (Jammal, 2019). In this context, standards for peanut quality and agri-food safety through manual harvesting have prevented grain damage, but producer choices have slowed production (Heuert et al., 2020). Despite challenges, growth opportunities exist for all sectors of the chain (Fiesp, 2021), with the understanding that the connection between soil-climatic factors and crop management to profitability and grain quality impacts peanut production costs (Dias et al., 2019; Pereira et al., 2023; Saath et al., 2021). Therefore, quantifying and qualifying the productive potential based on peanut genetic origin allows for differentiation of cultivars and identification of the most productive ones at regional levels (Bazanella et al., 2021; Bavier, Heuert & Sassuna, 2022). Considering this, the study aimed to evaluate the productive potential and grain quality of peanut cultivars and genotypes cultivated in the northwest region of Paraná.

2. Materials and Methods

The study on peanut cultivation was conducted at the Experimental Field of the Irrigation Technical Center (CTI) of the State University of Maringá (UEM), Maringá-PR, using eight lines, comprising four cultivars and four genotypes of peanuts from the Peanut Breeding Program (PMA) of EMBRAPA. The treatments were arranged in a randomized complete block design with four replications. The soil in the cultivation area is characterized as Dystroferric Red Nitosol (Santos et al., 2018) with a very clayey texture (72% clay content). The experimental plots measured 10.8 m² (3.6 x 3.0 m), consisting of four rows spaced 0.9 m apart, with a density of 18 plants per meter. At sowing, the seeds were treated with fipronil, pyraclostrobin, and thiophanate-methyl. Manual control was adopted for weed management throughout the crop cycle, and for pest and disease control, products approved by the Paraná Agricultural Defense Agency (Adapar, 2022) were used according to the level of infestation/attack. For rainfed cultivation, base fertilization was applied using 120 kg ha^{-1} of P_2O_5 (single superphosphate) and 60 kg ha^{-1} of K_2O (potassium chloride), based on soil chemical analysis (Table 1) and fertilization recommendations for the crop (Pauletti & Motta, 2019).

Table 1. Chemical characterization of the soil before cultivation, in the layer from 0 to 0.2 m depth

Depth	K	Ca	Mg	H+Al	Al	CTC	M	V
(m)	------------------------cmol$_c$ dm^{-3}-----------------------						---------%--------	
0.00 – 0.20	0.36	4.03	1.83	3.52	0.04	9.74	0.64	63.86
0.20 – 0.40	0.15	2.93	1.40	3.37	0.14	7.85	3.03	57.07
Depth	P	S	Cu	Fe	Mn	Zn	MO	pH
(m)	-------------------mg dm^{-3} -------------------						g dm^{-3}	($CaCl_2$)
0.00 – 0.20	4.24	6.55	16.56	62.28	111.96	1.68	1.71	5.00
0.20 – 0.40	1.73	16.62	15.96	58.14	43.38	0.18	0.89	4.80

The crop was evaluated in the field for emergence rate per plot at seven and 14 days after sowing (DAS). Height and diameter were measured on four plants per plot (from 9h to 11h) at 30 and 60 days after emergence (DAE); SPAD index (Soil Plant Analysis Development) readings were taken at 60 and 100 DAS. At 100 DAS, plant severity of early leaf spot (*Cercosporidium personatum*) was evaluated using a diagrammatic scale with scores ranging from 1 to 9 for the crop (Moraes, 2007).

To characterize the quality of harvested peanuts, germination test, electrical conductivity, and seedling biomass were evaluated at the Post-Harvest Technology Laboratory of Agricultural Products at the State University of Maringá (UEM), using a completely randomized design (CRD) with 4 replications. For the germination test, germitest paper was moistened with distilled water (three times its weight), and 50 seeds previously submerged in a 15% sodium hypochlorite solution for 5 minutes were sown on the germitest paper for each replication. They were kept in a germination chamber at 25°C ± 2, and germinated seeds were counted daily from the fourth to the tenth day (Brasil, 2009). From the data, the germination speed index (IVG), coefficient of germination speed (CVG), percentage of germinated seeds, hard seeds, and dead seeds were calculated.

For biomass measurement, seedlings were divided into shoots and roots, weighed on a precision analytical balance, and dried in a forced-air oven at 80±2°C for 24 hours. Total dry biomass, shoot mass, and root mass (mg plant^{-1}) were obtained by subtracting initial and final weights; the ratio between root mass and shoot mass was calculated from these results.

The electrical conductivity test, with five replications per treatment, involved weighing 10 seeds per sample, soaking them in 75 mL of distilled water, and incubating them at 25°C ± 2 in a BOD incubator for 24 hours. The conductivity index (µS cm^{-1}) related to grain mass was determined using a conductivity meter, with results expressed in µS cm^{-1} g^{-1}. Data were analyzed by analysis of variance (ANOVA) using the F-test, and means were compared by Scott-Knott test at 5% probability using SISVAR software (Ferreira, 2019).

3. Results

Analyzing the average values, significant differences were observed in the variables field emergence (EC), biophysical parameters (height and diameter), Soil Plant Analysis Development (SPAD) index, and incidence of black spot on peanut plants (Table 2). When analyzing the EC data, it was found that the BRS421 OL line, with 93.38%, showed the lowest emergence, and at 100 DAE, it presented plants with a height of 27.83 cm and a width of 93.98 cm, values similar to the BRS423 OL treatment and superior to 2173 OL. The plants from the BRS425 OL, BRS427 OL, 2055 OL, 2091 OL, and 2246 OL treatments showed higher values for plant height and width at 100 DAE, whose plants exhibited black spot incidence at medium to high levels (Table 2). Despite the use of fungicides to control cercosporiosis (black spot), high severities of black spot were observed in both cultivar and genotype plots.

Table 2. Mean values of field emergence (%EC) at 7 and 14 days after sowing (DAS), biophysical data (plant height and diameter in cm) at 30, 60, and 100 days after emergence (DAE), Soil Plant Analysis Development (SPAD) chlorophyll index at 60 and 100 DAE, and black spot (BS) incidence on peanut plants at 100 DAE

Lineage	% EC		Plant height (cm)			Plant diameter (cm)			SPAD		MP
	7	14	30	60	100	30	60	100	60	100	(Score)
BRS421 OL	42.25c	93.88b	10.63b	27.81b	27.83b	32.19b	92.95b	93.98a	54.48a	52.18a	3.7c
BRS423 OL	58.75b	99.50a	11.44 a	28.66b	28.68b	33.23a	93.65a	93.99a	50.85b	50.81b	6.0a
BRS425 OL	69.13a	99.75a	09.81b	30.50a	30.52a	31.39c	92.60b	93.66a	48.13c	48.13c	6.5a
BRS427 OL	44.25c	98.88a	10.63b	30.98a	31.03a	32.19b	93.55a	93.98a	54.42a	53.98a	6.5a
2055 OL	46.25c	97.98a	10.63b	31.81a	31.84a	32.19b	91.92c	93.68a	54.48a	52.28a	5.5b
2091 OL	69.63a	98.75a	09.81b	30.50a	30.54a	31.39c	93.60a	93.98a	48.43c	48.12c	6.2a
2173 OL	58.75b	95.50b	11.44a	22.66c	25.76c	33.23a	93.15a	93.80a	47.16c	47.95c	4.5b
2246 OL	69.13a	99.75a	09.96b	31.50a	31.52a	31.39c	92.60b	93.69a	49.98b	49.91b	4.5b
CV	0.1621	0.0911	0.1013	0.1302	0.1021	0.092	0.0516	0.0560	0.0486	0.0491	0.1242

*Distinct letters in the column differ from each other according to the Scott-Knott test at a 5% significance level.

Analyzing the performance of the peanut crop (Table 3), it was found that the 2173 OL genotype presented higher yields for hundred-grain weight (61.94 g) and productivity (5129.31 kg ha^{-1}) compared to the values of the BRS427 OL cultivar (59.28 g and 4368.77 kg ha^{-1}), BRS421 OL (56.98 g and 3785.89 kg ha^{-1}), and the 2055 OL genotype (49.38 g and 3225.45 kg ha^{-1}), respectively. For the variables performance, grain integrity (indicated by conductivity), and plant biomass accumulation (Table 3), varied responses with significant differences between treatments were observed, recording the lowest hundred-grain weight (49.38 g) and productivity (3225.45 kg ha^{-1}) for the 2055 OL genotype, which showed the highest index (5.91 µS cm^{-1} g-1) of electrical conductivity of the solution.

In the comparison of productivity values and hundred-grain weight, higher yields were observed in the 2173 OL and 2091 OL genotypes. However, the highest seedling biomass accumulation (230.44 mg) was found in the 2246 OL genotype plants, whose productivity (3845.89 kg ha^{-1}) was 25.02% lower than that of 2173 OL (5129.31 kg ha^{-1}) and 24.29% lower than that of 2091 OL (Table 3), indicating the 2246 OL genotype has lower competitive potential, with preference given to the one with higher productivity for the success of the crop in the region.

Table 3. Weight of 100 grains (P100G), productivity (P), electrical conductivity (EC) of peanut, seedling biomass (mg seedling^{-1})

Treatment	P_{100G}	P	CE	BMP	MPA	MR	Ratio
	(g)	(kg ha^{-1})	(µS cm^{-1} g^{-1})	(mg seedling^{-1})			
BRS421 OL	56.98b	3785.89c	3.21a	179.00c	118.82b	60.18d	0.509c
BRS423 OL	58.39a	3431.80d	4.73b	219.19b	148.36a	70.83c	0.477c
BRS425 OL	58.82a	4424.84b	3.29a	185.19c	124.12b	61.07d	0.492c
BRS427 OL	59.28a	4368.77b	2.70a	185.95c	122.41b	63.53d	0.519c
2055 OL	49.38c	3225.45d	5.91c	215.77b	132.17b	83.60b	0.633b
2091 OL	56.26b	5079.74a	3.24a	228.42a	131.85b	96.57a	0.732a
2173 OL	61.94a	5129.31a	2.91a	226.31a	142.73a	83.58b	0.482c
2246 OL	56.39b	3845.89c	4.76b	230.44a	141.76a	88.68a	0.626b
CV	0.2810	0.0917	0.2011	0.1053	0.0856	0.1106	0.1312

*Distinct letters in the column differ from each other according to the Scott-Knott test at a 5% significance level.

It was possible to distinguish different germination speeds based on the seed water content, suggesting a direct relationship between speed and seed vigor, with a higher Germination Speed Index (IVG) at the dry weight water contents of 0.892, 0.895, and 0.815, respectively. A germination percentage below 80% and a longer period to complete the germination process indicate the presence/action of biotic agents (fungi) or abiotic agents hindering the reactivation of the metabolic process.

Table 4. Seed moisture content on a dry weight basis (Ubs), Germination Speed Index (IVG), mean germination time (TMG), germination percentage (%G), Germination Velocity Coefficient (CVG), root length (CR), and hypocotyl length (CH) of the seedlings were evaluated

Treatment	Ubs	IVG	TMG	CVG	G	Dead	Hards	CR	CH
	(decimal)		(days)	--------------------- (%) -------------------				**------ cm -------**	
BRS421 OL	0.712b	56.7b	6.12b	46.12 a	77.69a	19.29a	3.02c	8.80b	9.86b
BRS423 OL	0.892a	78.0a	5.48c	46.48 a	82.83a	12.60c	4.57c	9.98a	10.96a
BRS425 OL	0.751b	60.0b	6.34b	46.34 a	72.28b	14.09c	13.62b	8.98b	10.01b
BRS427 OL	0.612c	37.2c	7.88a	45.18b	62.88c	33.60a	3.52c	8.56b	10.21b
2055 OL	0.608c	34.2c	7.68a	44.68b	60.97c	33.02a	6.01c	9.56a	10.16b
2091 OL	0.723b	57.0b	6.09b	46.50a	60.33c	35.66a	4.01c	8.02c	10.08b
2173 OL	0.895a	77.2a	5.16c	46.46a	82.25a	12.19c	5.56c	9.85a	10.73a
2246 OL	0.815a	76.5a	7.64a	46.26a	61.87c	24.41b	13.72a	7.98c	8.65c
CV		0.2389		0.0609	0.2383	0.4699	0.6254	0.0412	0.0398

*Distinct letters in the column differ from each other according to the Scott-Knott test at a 5% significance level.

4. Discussion

Associated with the plant's photosynthetic capacity, the more leaves produced, the larger the area for energy capture for photosynthesis. Thus, assuming that the chlorophyll index (SPAD) of the plants can indicate the availability of foliar nitrogen, a variation in values (Table 2) between the evaluated lines was observed, with the highest values found in the plants of the BRS421 OL and BRS427 OL cultivars of the 2055 OL genotype. However, considering that 50 to 70% of the total nitrogen in the leaves may be allocated in proteins (Dantas et al. 2012), such as nitrate reductase, which are associated with chloroplasts (REIS et al., 2006), it is partially justified that a lower SPAD index does not always mean a lower foliar nitrogen content. The severity of the black spot observed in the plants of the 2055 OL genotype (Table 2), which caused considerable defoliation, may explain the lower productivity (Table 3).

Signs of problems in grain integrity and/or inferior quality of the grains were observed in the genotypes (2091 OL, 2173 OL, and 2246 OL) and cultivars (BRS421 OL, BRS423 OL, BRS425 OL, and BRS427 OL). According to the results (Table 3), there is a noticeable difference in the electrical conductivity (EC) values of the evaluated grains, with lower indices (µS cm^{-1} g^{-1}) found in the treatments 2173 OL, BRS421 OL, 2091 OL, and BRS425 OL, respectively, suggesting superior grain quality, which can be confirmed as meeting peanut quality standards. A lower accumulation of seedling biomass (Table 3) can lead to decreases in peanut production, either due to reduced grain weight and/or fewer pods. Vegetation indices are associated with the bio-physical characteristics of the seedling (shoot and root), with plant biomass being essential for green manure, improving soil properties and providing nutrients, such as nitrogen, to peanut plants and/or other crops in the next planting season.

The bio-physical parameters (total biomass, dry mass of the shoot and root) between treatments (Table 3) vary somewhat (mg) in relation to grain weight and plant productivity (g and kg ha^{-1}). It was observed that the peanut plants from the genotypes, to some extent, adapted well to the edaphoclimatic conditions of the Maringá region, especially the plants of 2091 OL and 2173 OL, which have potential for the application of genetic improvement for the development of peanut cultivars suited to the regional conditions.

The germination percentage (Table 4) informs us of the total number of germinated seeds, without indicating the actual time of the process, making it difficult to identify similar germination rates, especially when considering plant emergence and vigor. According to Marangoni et al. (2014), less vigorous seeds require a higher average number of days to germinate. Therefore, if germination occurs at the beginning of sowing, the emergence rate will be higher. In this process, considering the differences between seeds for water absorption, it is necessary to allow more or less time for them to germinate. The results for the germination speed index (IVG) showed variations between cultivars and genotypes (Table 4), indicating that the seed water content directly affected the IVG. The lower water availability in the seed suggests a longer time for absorption, which can reduce the germination speed, with the results showing that the shorter the germination time, the higher the germination speed, and a lower IVG was observed for seeds with lower water content, indicating a delay in seed germination.

The germination potential is associated with temperature and humidity conditions of the environment, which, in the absence of control, promote sorption phenomena (Sá et al., 2021), favoring the metabolic activity of biotic agents and hindering the conservation of seeds or grains (Erten & Cadwallader, 2017; Sarath et al., 2016).

Analyzing Table 4, it was observed that seeds with water content between 0.900 and 0.700 (dry basis) had the highest germination speed coefficient (CVG) and did not show significant variation according to the Scott-Knott test ($p \geq 0.05$), differentiating them from seeds with lower water content. Studies report that seeds with a higher germination speed coefficient (CVG) are more vigorous. Considering that the lower the mean germination time (TMG), the higher the germination speed. In this study, the highest average time to reach maximum germination (days) was observed in seeds with water content (dry basis) of 0.608 (genotype 2055) and 0.612 (cultivar BRS427), which took 19.79 to 34.36% longer to reach maximum germination compared to seeds from other treatments with average water content between 0.700 and 0.900 on a dry basis.

According to the data, the growing environment influenced the dry mass production of different plant parts, with the greatest root length (RL) and hypocotyl (HC) observed in the BRS423 OL and 2173 OL treatments. The radicle will give rise to the plant's root, so a plant growing with an abnormal root will face restrictions in accessing water and nutrients at greater depths. The low-quality indices of the grains (Table 4) can be explained by the pre-harvest and harvest climatic conditions of the peanut.

The high frequency of contamination is due to failures in controlling humidity and temperature throughout the production chain, conditions favorable to the development of toxigenic fungi such as Aspergillus flavus and A. parasiticus (FIESP, 2020). In general, the adaptability level of the tested lines indicates, through the productive indices achieved by the crop (Table 3), a high potential for the morphoclimatic conditions of interest. The evaluation identified that genotype 2173 OL was less affected by the black spot disease (score 4.5) compared to the cultivars (score 6.0 to 6.5), except for BRS421 OL (score 3.7), indicating good adaptation to the environmental conditions of Maringá/PR. The bio-physical parameters and eco-physiological factors are related to plant development and, consequently, affect peanut productivity under edaphoclimatic conditions.

The choice of cultivars more adapted to combined factors such as light, temperature, relative humidity, and soil characteristics for cultivation and crop management is crucial and should be considered. The hundred-seed weight is an important variable for comparing and estimating vigor between different batches of the same cultivar or even between cultivars, where seeds with higher hundred-seed weight have a larger reserve of nutrients available for use during germination and initial seedling development (RAS, 2012).

The higher productive performance of the genotypes 2173 OL and 2091 OL (large seeds), the median performance of the cultivars BRS425 OL and BRS427 OL (medium seeds), being superior to BRS421 OL and genotype 2246 OL (medium seeds), cultivar BRS423 (large seeds), and genotype 2055 OL (small seeds), can be explained by the genetic constitution of these lines, which are characterized by medium-sized pods (Embrapa, 2022) under experimental conditions, having between 1 and 3 seeds (average weight) per pod. This indicates that the productive potential was less influenced by the environment and cultivation conditions than by genetics.

5. Conclusion

Significant differences were observed between the treatments for the variables analyzed. Productivity ranged from 3225.45 kg ha^{-1} to 5129.31 kg ha^{-1}. The genotypes 2173 OL and 2091 OL, as well as the cultivars BRS 425 OL and BRS427 OL, achieved the best productive performance. The cultivar BRS421 OL and the genotype 2173 OL exhibited lower severity of black spot disease. Under the edaphoclimatic conditions of management and cultivation, genetic origin influenced the productive potential of the tested lines.

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Authors contributions

Reni Saath was responsible for the study design and data collection. Reni Saath and Gustavo Lopes Pereira drafted the manuscript. Gustavo Soares Wenneck, Jair Heuert, and Tais de Moraes Falleiro Suassuna revised it. All authors read and approved the final manuscript.

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Obtained.

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No additional data are available.

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