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Characteristics of Maize plants predicting resistance to the Stink Bug *Diceraeus (Dichelops) melacanthus* (Dallas, 1851) (Hemiptera: Pentatomidae)

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ABSTRACT. The green-belly stink bug, *Diceraeus melacanthus* (Dallas, 1851) (Hemiptera: Pentatomidae), is a pest in the early stages of maize cultivation. Both adults and nymphs feed on plant sap, causing injuries to the plant that result in reduced productivity. To identify the characteristics present in maize genotypes that enable the selection of genotypes resistant to this pest infestation, we evaluated the effect of plant growth rate and initial development on injury reduction. The experiments were conducted in a greenhouse at Embrapa Maize and Sorghum, in Sete Lagoas, with 35 maize hybrids developed under the breeding program in commercial or pre-commercial stages. We evaluated (i) characteristics that conferred a higher initial development speed of maize; and (ii) stink bug injury in twelve maize hybrids. The evaluated characteristics were: phenological stage, plant height, stem diameter, and injury score. The obtained data were subjected to Pearson correlation, linear regression, ANOVA, and the Scott-

Knott test at 5% significance in the R software. As a result, we found that plant height (d.f.= 46, p< 0.001, r= -0.868) had a negative correlation with the injury score, meaning that the greater this characteristic in the plant, the less the injury received. The phenological stage (d.f.= 46, p< 0.001, r= -0.618) and stem diameter (d.f.= 46, p= 0.036, r= -0.036) also showed this trend, but to a lesser extent. We conclude that growth parameters in the early development stages of maize plants are effective in determining resistance to stink bug injury and are therefore important characteristics for the selection of genotypes resistant to this pest.

Key words: Genotypic Variation; Injury; Second Crop; IPM; Escape; Resistance.

INTRODUCTION

The green-belly stink bug, *Diceraeus melacanthus* (Dallas, 1851) (Hemiptera: Pentatomidae), is a primary pest of maize when cultivated in the second crop season after soybean cultivation. Conditions in this scenario are favorable for the development of the pest insect as the second crop planting is linked to soybean as the previous crop which can provide a 'green bridge' between soybean and maize. This bridge supplies the stink bug with the necessary shelter and food to survive and complete its life cycle (Ferreira et al., 2017).

When feeding on maize seedlings, the adults of *D. melacanthus* not only cause a reduction in plant weight but also lead to lower grain yield, and affect growth and development if present in the planting area when the plant is between phenological stages V1 and V3. In more severe infestations, the attacked plant becomes unproductive, compromising productivity (Fernandes et al., 2020). Such injuries are detrimental to maize until the V5 development stage. In terms of periods, the stages from V1 to V5 comprise approximately 10 to 30 days after planting (Santos et al., 2021). After this stage, maize becomes less susceptible to injuries caused by pest feeding.

Control and mitigation strategies for the problems arising from pest infestations have primarily focused on the use of chemical insecticides, either for seed treatment or direct plant spraying. Plant resistance to this pest is one of the strategies that has recently been studied to potentially incorporate into pest management. Simão et al. (2023) studied several commercially available maize hybrids regarding their non-preference for feeding (antixenosis), as the reduction in feeding punctures implies a reduction in injuries. This approach is promising and should not be neglected; however, it should be considered alongside other characteristics that confer resistance to stink bugs. Antibiosis, which involves altering the insect's biology, may not be the most suitable control mechanism, as it does not reduce plant injuries and, consequently, does not lead to a reduction in the damage caused by the pest (Canassa et al., 2017).

Genetic improvement of plants aimed at pest resistance plays a fundamental role in insect management. In this scenario, the goal is to select superior genotypes that possess genetic characteristics making them less attractive, less favorable to development, or less susceptible to insect damage (Amabile et al., 2018). Obtaining these genotypes involves selecting those that show less injury from the studied pest attack and measuring the plant characteristics associated with this lower injury to achieve the established purposes of the breeding program. Thus, it is generally necessary to expose the evaluated genotypes (i.e. the plants) to insect attacks to evaluate and select the resistant ones.

As genetic improvement typically involves evaluating a large number of genotypes, it is crucial to use easily measurable phenotypic characteristics, thus improving the feasibility and, consequently, the selection process. In the present study, we aim to select predictive characteristics of resistance to the green-belly stink bug without the need for pest infestation for initial evaluation, which would greatly facilitate the selection of resistant genotypes for a breeding program.

The selection of plant characteristics that act as predictors of resistance constitutes a process that makes the identification of resistant genotypes more accessible and efficient. This is because conducting bioassays with stink bugs is a costly and complex step, making it difficult to apply on a large scale, especially when it involves evaluating a large number of genotypes, as is commonly required in breeding programs.

Thus, with the aim of evaluating characteristics of maize plants that are predictors of resistance to the green-belly stink bug, we developed the present study, focusing on escape, considering that plants that develop more rapidly in the field may be less susceptible to pest infestation. We therefore evaluated (i) characteristics that conferred greater initial development speed in 35 maize hybrids; and (ii) stink bug injury in maize hybrids.

MATERIAL AND METHODS

For the present study, two experiments were conducted in a greenhouse at Embrapa Maize and Sorghum, Sete Lagoas-MG (19º28'S, 44º15'W, alt 732 m), between the months of June and October (Current: 25°C; Min: 12.2°C; Max: 45.3°C; RH: 58%).

Bioassay 1

In the first bioassay, 35 maize genotypes from Embrapa Maize and Sorghum's breeding program, including experimental, commercial, and pre-commercial hybrids, were evaluated without stink bug infestation. The aim was to evaluate the predictive characteristics of resistance in different hybrids and highlight the cultivars with the highest and lowest yields, ranking them for a second phase. The evaluated genotypes were: 1Q2366, 1R2536, 2R2642, 1R2620, 1Q2427, 1Q2400, 1Q2425, 1Q2370, 1Q2473, BRS1055, 1P2206, 1S2719, 1S2634, 3S2787, 3S2761, 3S2755, 1S2722, BRS3042, BRS3042 VTPRO2, 1S2748, 1S2747, 3S2731, SHS7930 VTPRO2, 3S2777, 2S2637, 1S2718, 3S2734, BM270 PRO2, 1S2726, 3S2772, 3S2770, AG8061 VTPRO2, 1S2728, 3S2730, and 1F640 VTPRO2.

Planting was done in 12-liter pots with soil fertilized with two grams of urea. Five pots were used for each genotype, with three seeds per pot, representing 35 treatments with five replications each, and an experimental plot of three plants per replication. The experimental design used was completely randomized. 20 days after emergence, the following was evaluated: the phenological stage of the plants (including the cotyledon leaf), stem diameter with a digital caliper, and plant height (from the soil to the region of the leaf collar, visible with the ligule and auricle), with the aid of a graduated ruler.

Bioassay 2

In the second bioassay, 12 genotypes were selected based on the results of the first trial. Eight hybrids were chosen for their contrasting composite weighted averages, and another four were selected according to stock availability and their history with sap-sucking insects, for evaluation in a completely randomized experimental design with four replications. The contrasting maize genotypes selected from the first trial's results were: 2R2642, 1P2212 VTPRO2, 3S2734, 3S2761, 1P2206 VTPRO2, 1P2215 VTPRO2, 1R2536, 1Q2366, BRS3042 VTPRO2, 1F640 VTPRO2, 1Q2425, and 1T2789. Planting was carried out in 12-liter plastic pots with soil fertilized with two grams of urea. Two seeds were sown per pot, with thinning to one plant per pot after emergence.

Two-liter transparent white PET plastic bottles were used, perforated along the entire length to allow air passage and prevent the escape of the stink bug. The bottles were cut in half, with the open end used to secure the pot with soil.

After the emergence of maize seedlings, about five days after planting, three adult stink bugs were placed in each cage, with four pots. The cages were inspected daily to evaluate the escape or death of the stink bugs. If necessary, the insects were replaced.

Stink bug injuries were evaluated 20 days after emergence. To recognize and identify the level of visual damage on maize plants caused by the green-belly stink bug, the damage classification scale proposed by Bianco (2004) was used, where a score of zero equals a plant with no attack and free of damage, and a score of four represents a plant with the maximum manifestation of pest attack. From emergence, five days after planting, to the removal of insects, 20 days after emergence, measurements of plant height, phenological stage, and stem diameter were taken every five days over 30 days, following the same protocols as the previous experiment. However, for this manuscript, only data up to 20 days after emergence were used, where the plant was in the V3-V4 stage, a critical period for stink bug injuries.

To determine the final ranking of hybrids, a weighted average of the data was calculated. Each value of the characteristics (score, height, stage, and diameter) was multiplied by its respective weight, these products were summed, and the total was divided by the sum of the weights. The weights were determined based on the ranking we performed for each evaluated parameter; hybrids with the same value received the same weight, and the first in the ranking had the highest weight. For the injury score, we used the median, where the first ranked was the one with the lowest score. In the other parameters, we used the mean, with the first ranked being the one with the highest value. Thus, each value contributed proportionally to the average according to its relative importance.

The formula used to calculate the composite weighted average (CWA) for each hybrid was (Eq. 1):

CWA= ((Score*Weight + Stage*Weight + Height*Weight + Diameter*Weight)) / ((Score + Stage + Height + Diameter))

(Eq. 1)

The data were subjected to Pearson correlation to understand if there is a linear relationship between the attributes. Linear regression analysis was conducted to understand the impact on the relationships between plant characteristics and the injury score, and analysis of variance (ANOVA) and the Scott-Knott mean test, with a significance level of 5%, for comparing means between genotypes. The analyses were performed using the R statistical program (R Development Core Team, 2014).

RESULTS

Predictive Characteristics of Resistance – Bioassay 1

In the first experiment, based on the results collected 20 days after emergence, it was possible to select hybrids with greater potential for resistance and escape from injuries caused by stink bug feeding, possibly through the rapid initial development of maize plants and other characteristics. Thus, significant differences were observed in the phenological stage of the plants at 20 days of evaluation (Table 1), with 21 hybrids (1P2206, 1Q2366, 1Q2400, 1Q2425, 1Q2427, 1Q2473, 1R2620, 1S2634, 1S2719, 1S2747, 2R2642, 3S2730, 3S2731, 3S2734, 3S2755, 3S2761, 3S2787, BRS1055, BRS3042, BRS3042VTPRO2, SHS7930VTPRO2) being in the V4 stage, and receiving the same classification by the Scott-Knott statistical test. On the other hand, 12 hybrids (1Q2370, 1R2536, 1S2718, 1S2722, 1S2726, 1S2728, 1S2748, 2S2637, 3S2770, 3S2772, 3S2777, BM270 PRO2) were in the V3 stage, being placed in the same group, and two of them (1F640 PRO2 and AG8061PRO2) in V2, differing from the others and having the lowest number of fully expanded leaves (Table 1).

For plant height, 18 cultivars (1P2206, 1Q2366, 1Q2400, 1Q2425, 1Q2427, 1Q2473, 1R2536, 1R2620, 1S2722, 1S2747, 2R2642, 3S2734, 3S2755, 3S2761, 3S2787, BRS1055, BRS3042, BRS3042VTPRO2) were classified in the same group, having a greater height with an average of 17.57 cm, and differing from the other group, with 17 plants (1P2206, 1Q2366, 1Q2400, 1Q2425, 1Q2427, 1Q2473, 1R2536, 1R2620, 1S2722, 1S2747, 2R2642, 3S2734, 3S2755, 3S2761, 3S2787, BRS1055, BRS3042, BRS3042VTPRO2) and an average of 14.35 cm.

For stem diameter, 31 hybrids (1P2206, 1Q2366, 1Q2370, 1Q2400, 1Q2425, 1Q2427, 1Q2473, 1R2536, 1R2620, 1S2634, 1S2718, 1S2719, 1S2722, 1S2726, 1S2728, 1S2747, 1S2748, 2R2642, 2S2637, 3S2730, 3S2731, 3S2734, 3S2755, 3S2761, 3S2770, 3S2772, 3S2787, BM270 PRO2, BRS1055, BRS3042, BRS3042VTPRO2) had thicker stems, with an average of 0.79 cm, differing from four other hybrids, with an average diameter of 0.61 cm (1F640 PRO2, 3S2777, AG8061PRO2, SHS7930PRO2).

Considering all the evaluated characteristics, namely phenology, plant height, and stem diameter, which are important components of the plant's initial development, out of the 35 evaluated hybrids, 16 (1Q2400, BRS3042VTPRO2, 2R2642, 1Q2425, 1Q2366, 1Q2473, BRS1055, 1P2206, BRS3042, 3S2787, 3S2761, 1Q2427, 3S2734, 3S2755, 1S2747, 1R2620) would be the most likely candidates to exhibit resistance to the green-belly stink bug *D. melacanthus*.

Validation of Predictive Characteristics of Resistance with Stink Bug – Bioassay 2

In the second experiment, the results of the Pearson correlation (Table 2) showed statistically significant relationships between various parameters of the evaluated hybrids. The injury score had a strong negative correlation with plant height ($r = -0.868$; $p < 0.001$), indicating that plants with lower injury tend to be taller. There was also a moderate negative correlation between the injury score and the phenological stage ($r = -0.618$; $p < 0.001$), suggesting that plants at more advanced phenological stages exhibit lower injury. Plant height was positively correlated with the phenological stage ($r = 0.738$; $p < 0.001$), indicating that taller plants tend to be at more advanced phenological stages. Additionally, a moderate positive correlation was observed between plant height and stem diameter ($r = 0.434$; $p = 0.002$), showing that taller plants also tend to have thicker stems. Finally, the injury score had a weak but significant negative correlation with stem diameter ($r = -0.303$; $p = 0.036$),

Table 1. Evaluation of phenological stage, height, and stem diameter measured 20 days after emergence, in a greenhouse, of 35 different maize hybrids in the first experiment. Sete Lagoas, (2024).

	HYBRID	**PHENOLOGICAL STAGE**		**PLANT HEIGHT (cm)**		**STEM DIAMETER (cm)**	
1	1F640 PRO.2	2.90	C	12.10	B	0.56	B
2	1P2206	4.00	A	16.85	A	0.77	A
3	1Q2366	4.00	A	18.49	A	0.84	A
4	1Q2370	3.43	B	14.38	B	0.77	A
5	1Q2400	4.07	A	19.42	A	0.94	A
6	1Q2425	4.00	A	19.35	A	0.80	A
7	1Q2427	3.93	A	17.58	A	0.79	A
8	1Q2473	4.00	A	17.43	A	0.72	A
9	1R2536	3.53	B	17.13	A	0.76	A
10	1R2620	3.73	A	18.03	A	0.76	A
11	1S2634	3.93	A	14.56	B	0.79	A
12	1S2718	3.47	B	14.51	B	0.80	A
13	1S2719	3.87	A	15.25	B	0.79	A
14	1S2722	3.60	B	16.78	A	0.73	A
15	1S2726	3.27	B	15.01	B	0.73	A
16	1S2728	3.40	B	13.96	B	0.86	A
17	1S2747	3.80	A	17.20	A	0.84	A
18	1S2748	3.40	B	15.13	B	0.74	A
19	2R2642	4.00	A	19.73	A	0.90	A
20	2S2637	3.67	B	14.84	B	0.84	A
21	3S2730	3.73	A	13.71	B	0.80	A
22	3S2731	3.93	A	15.19	B	0.76	A
23	3S2734	3.93	A	16.55	A	0.77	A
24	3S2755	3.87	A	16.36	A	0.76	A
25	3S2761	3.93	A	17.82	A	0.85	A
26	3S2770	3.57	B	15.48	B	0.75	A
27	3S2772	3.40	B	15.08	B	0.73	A
28	3S2777	3.60	B	14.53	B	0.61	B
29	3S2787	4.00	A	16.06	A	0.77	A
30	AG8061PRO.2	2.93	C	11.27	B	0.60	B
31	BM270 PRO. 2	3.60	B	13.70	B	0.75	A
32	BRS1055	4.00	A	16.85	A	0.81	A
33	BRS3042 CONV	4.00	A	16.54	A	0.78	A
34	BRS3042 PRO.2	4.07	A	17.91	A	0.87	A
35	SHS7930 PRO. 2	4.00	A	15.10	B	0.68	B

*Means separated by the Scott-Knott test at 5% probability.

Table 2. Pearson correlation between the attributes of the evaluated hybrids (phenological stage, plant height, stem diameter, and injury score). Positive values indicate direct correlation, while negative values indicate inverse correlation. The correlation intensity is indicated by the magnitude of the values. Sete Lagoas, (2024).

		Injury score		Phenological stage		Plant height		Stem diameter
Injury score	Pearson's R	—						
	p-value	—						
Phenolog. stage	Pearson's R	-0.618	***	—				
	p-value	<.001		—				
Plant height	Pearson's R	-0.868	***	0.738	***	—		
	p-value	<.001		<.001		—		
Stem diameter	Pearson's R	-0.303	*	0.192		0.434	**	—
	p-value	0.036		0.191		0.002		—
Note. * p < .05, ** p < .01, *** p < .001								

suggesting that plants with lower injury tend to have thicker stems on average (Table 2).

Through linear regression, it was possible to observe and confirm that the injury score of the green-belly stink bug *D. melacanthus* was negatively related to the phenological stage (R2=0.41), plant height (R2=0.73), and, to a lesser extent, stem diameter (R2=0.08) (Figure 1). These results demonstrate that these variables are inversely proportional, meaning that the higher the value of the measured characteristics (X-axis), the lower the injury score (Y-axis) caused by the pest insect.

The principal component analysis explained 88% of the total variability in the first two components (Figure 2, Table 3). The variables phenological stage and plant height were allocated in the same quadrant, denoting the expected result that these variables are highly correlated and in the same direction. On the other hand, the injury score variable is in the opposite quadrant, suggesting a negative correlation with the others. Stem diameter did not show a correlation between the variables in the second and fourth quadrants, as it forms an angle close to 90 degrees.

Thus, the presented dataset allows us to conclude that higher injury scores are associated with shorter plant height, smaller stem diameter, and more advanced phenological stages. In this same context, the taller the plant, the more advanced its phenological stage.

Based on the composite ranking of plant characteristics and injury scores (Figure 3), we highlight five hybrids: 1) 2R2642: ranked first with a weighted arithmetic average of 123.34, standing out for its plant height (12.00 cm) and maintaining top positions in almost all criteria, with the lowest injury score (1.5) and good performance in other parameters; 2) 1Q2425: ranked second with a weighted average of 68.72. This hybrid performed well in height (11.50 cm) and excelled in stem diameter ranking (0.833 cm), presenting a robust combination of resistance and development; 3)

Table 3. Variance values (%) for component 1 and 2 variables.

Variables	PC 1	PC 2
Injury Score	-0.55024	0.15171
Phenological stage	0.50174	-0.35518
Plant height	0.59021	-0.043204
Stem diameter	0.31168	0.92139

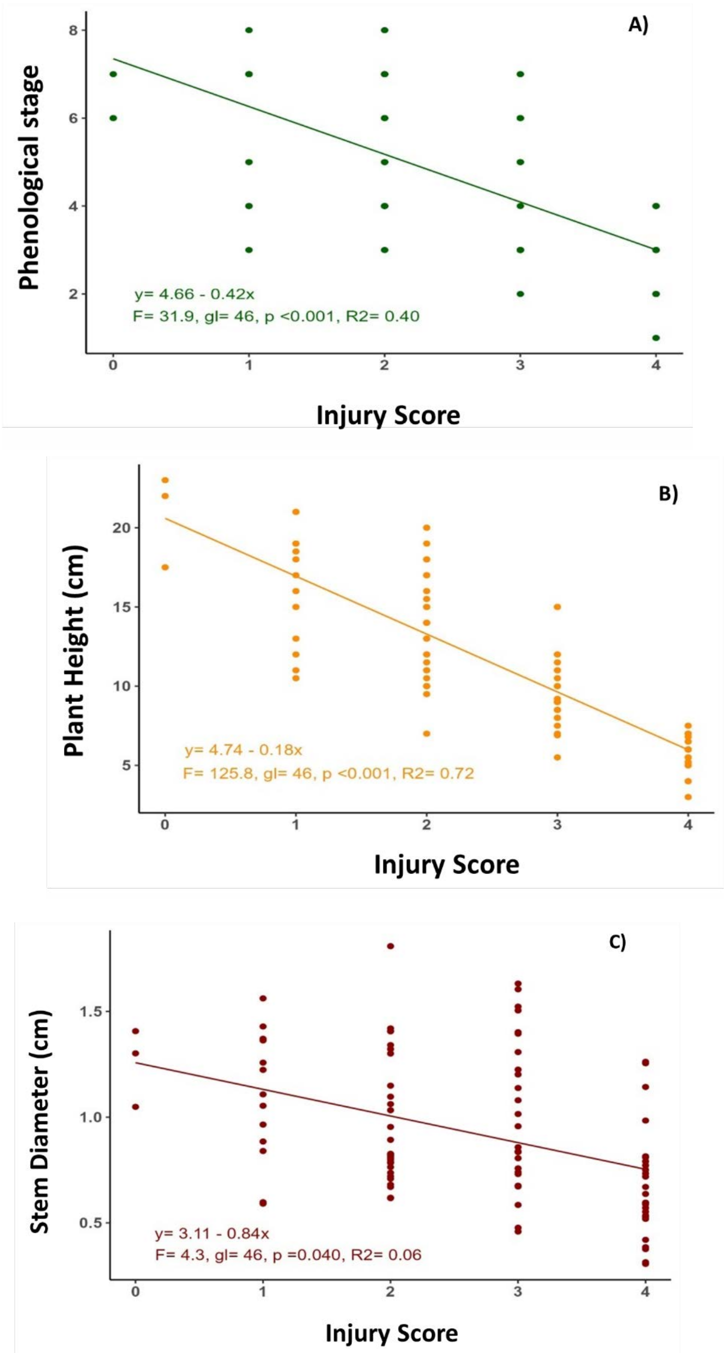

Figure 1. Relationship between the injury score of the green-belly stink bug *Diceraeus melacanthus* and phenological stage (A, F= 31.91, df= 46, p< 0.001, R^2= 0.40), plant height (cm) (B, F= 125.8, df= 46, p< 0.001, R^2= 0.72), and stem diameter (cm) (C, F= 4.31, df= 46, p= 0.040, R^2= 0.06) of maize. Sete Lagoas, (2024).

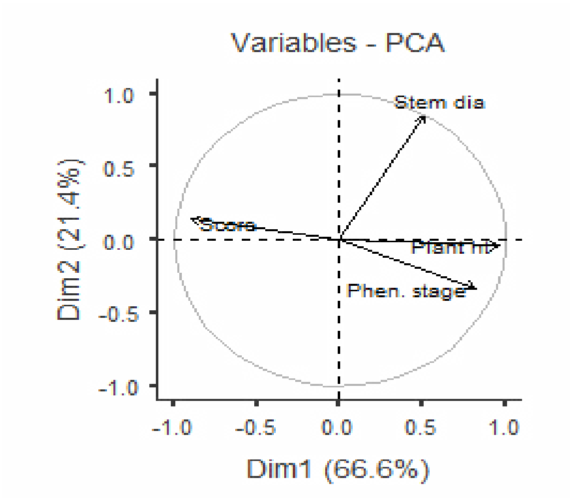

Figure 2. Principal Component Analysis (PCA) of predictive resistance characteristics: Injury score (Score), phenological stage (Phen. stage), plant height (Plant ht), and stem diameter (Stem dia) in maize plants. Sete Lagoas (2022).

Hybrid	Median Injury Score	Rank Score	Weight Score Injury	Average Phen. Stage	Rank Phen. Stage	Weight Phen. Stage	Average Plant Height	Rank Height	Weight Plant Height	Average Stem Diameter	Rank Diameter	Weight Diameter	Weighted Arithmetic Mean	Composite Rank
2R2642	1.5	1º	4	3.5	2º	5	12,00	1°	11	0.737	6°	7	123.34	1°
1Q2425	3	2º	3	4	1º	6	11.5	2°	10	0.833	2°	11	68.72	2°
1R2536	3	3º	3	3.25	3º	4	10,00	3°	9	0.913	1°	12	55.15	3°
1P2206VTPRO2	3	4º	3	3.25	4º	4	9,00	4°	8	0.652	8°	5	45.32	4°
3S2761	3	5º	3	2.75	10º	2	8.5	6°	7	0.778	4°	9	39.03	5°
1F640 VTPRO2	3.5	8º	2	3.25	6º	4	8.5	5°	7	0.822	3°	10	37.63	6°
1T2789	3	6º	3	3.25	5º	4	8.25	8°	5	0.545	12°	1	33.31	7°
1P2215 VTPRO2	3.5	9º	2	3	9º	3	8.33	7°	6	0.742	5°	8	32.63	8°
1Q2366	3	7º	3	2.75	11º	2	8,00	9°	4	0.574	11°	2	27.21	9°
3S2734	4	10º	1	3.25	7º	4	7.33	10°	3	0.649	9°	4	21.63	10°
1P2212 VTPRO2	4	11º	1	3.25	8º	4	7,00	11°	2	0.61	10°	3	19.07	11°
BRS3042 VTPRO2	4	12º	1	2.5	12º	1	5.5	12°	1	0.721	7°	6	12.80	12°

Figure 3. Final ranking of hybrids through the weighted arithmetic mean of injury score, phenological stage, plant height, and stem diameter.

1R2536: ranked third with a weighted average of 55.15. Its injury score (3.0) and height (10.00 cm) were satisfactory, and it showed a balanced performance in other parameters; 4) 1P2206 VTPRO2: ranked fourth with a weighted average of 45.32. This hybrid had an average height of 9.00 cm and maintained a good balance between resistance and growth, as seen in intermediate ranks; 5) 3S2761: ranked fifth with a weighted average of 45.32. This hybrid had a median injury score of 3.0 and remained competitive in most parameters, standing out for its stem diameter (0.778 cm).

DISCUSSION

The data obtained contribute to the understanding of factors and predictive characteristics of resistance to the green-belly stink bug in maize. It is important to note that our findings corroborate the work of Bueno et al., (2021), as the injuries caused by the stink bug in maize are significant in the initial development stage, when maize has up to five fully developed leaves. Thus, escaping the critical phase is an appropriate strategy for managing this pest

In this context, the results obtained in the first trial show the selection of hybrids based on characteristics that are easily measured under controlled conditions. Thus, we selected hybrids with higher values of the desired characteristics, which we refer to as plants with higher initial development speed. For the second trial, it was possible to evaluate the main hybrids selected based on the characteristics previously studied regarding stink bug infestation, allowing us to confirm our hypothesis. The data selection at 20 days after emergence, precisely when the plant is at the V4 stage, was based on the work of Lima et al., (2019), which shows that the highest leaf injuries occur between the V2-V4 stages of maize, and the smallest increase in plant height at the V4 stage. Similarly, Chiaradia et al., (2016) reiterates that the critical period for the incidence of this insect is up to V5.

The results of the Pearson correlation analysis revealed significant interactions between the evaluated phenological and morphological parameters, corroborating previous studies on the interaction between growth and resistance in plants (Aoyama and Labinas, 2012; Jacobsen et al., 2022).

The relationship between plant characteristics (phenological stage, stem height, and stem diameter) and the injury score, through linear regression (Figure 1), brought us a coefficient of determination (R2) with high and low values depending on the analyzed characteristic. Lower values were mainly for stem diameter, indicating that although this characteristic interferes with the injury score, other factors have a more pronounced effect on the expression of resistance to stink bugs. According to São João et al. (2016), plant growth and development influence the insect-plant interaction, as the qualitative and quantitative characteristics (texture, smell, height, diameter, etc.) produced during its life cycle function as a defense mechanism and may consequently result in less injury. Chiaradia (2016) states that the taller the plant, the more difficult it is for the sap-sucking insect to reach the plant's growth point with its stylet, thus, the damage will be minimal or none.

The phenological stage is directly related to plant growth. Phenology is important in decision-making of the cultivation site through morphological observation of the plant, as it represents the stages of growth and development of the plant, besides predicting crop yield and optimizing productivity (Câmara, 2006). Therefore, it is evident that the phenological stage is an important aspect of plant growth, reflecting on the leaf area and, consequently, on photosynthesis, having implications for agricultural production.

Stem diameter is also directly related to plant growth, as it is associated with biomass production, mechanical resistance, and plant support (Brito et al., 2014). Garcia (2022) states that the green-belly stink bug has difficulty feeding when encountering a thicker stem. Ávila (1995), Fernandes (2015), and Gomez (2001) also understand that the increase in lignin concentration in the maize plant stem hinders feeding and, therefore, results in a lower injury score. Chiaradia (2012) concluded that a diameter less than 0.8 cm is favorable for the insect. Relating this information to the evaluated data, out of the 48 assessed plants, 20 had a stem diameter above 0.8 cm (Table 1). Thus, out of the 20 plants with the largest diameter, two repetitions were of the cultivars 1F640 VTPRO2 (μ=0.904 cm), 1P2215 VTPRO2 (μ=1.02 cm), 2R2642 (μ=0.863 cm), 3S2761 (μ=1.22 cm), BRS3042 VTPRO2 (μ=0.883 cm); one repetition of 1Q2366 (μ=1.05 cm), 1T2789 (μ=0.806 cm), 3S2734 (μ=0.814 cm); three repetitions of 1Q2425 (μ=1.01 cm); and four repetitions of

1R2536 (μ=0.991 cm). The cultivar 3S2761 had the highest average stem diameter, and 1T2789 had the lowest average stem diameter.

Bridi et al., (2016) found that each additional stink bug feeding on a maize plant resulted in a 1.25 cm decrease in plant height and a 0.71-point increase in the injury score on the scale created by Roza-Gomes et al., (2011). Thus, the adoption of three stink bugs in the second experiment conducted in the present study enhanced the results to demonstrate resistant genotypes and confirm the selective efficacy of the characteristics used as predictors of resistance.

In this context, it is worth noting that the preliminary measurements of growth rate in the first experiment were made to correlate with the reduction of injuries caused by the stink bug in the second experiment. Thus, the method used, in addition to being easy to execute, indicates the changes in plant growth that favor the reduction of injuries caused by the stink bug, as the measured characteristics were effective for selecting resistant plants when subjected to infestation, meaning those with higher initial development speed showed lower injury scores in the second trial in response to green-belly stink bug attacks. Baldin et al., (2019) state that such characteristics related to initial development are predictors of resistance and, therefore, are crucial biological aspects for improving studies and techniques for resistance evaluation.

Various studies in literature report that plant structures can interfere with insect feeding and thus minimize damage. For example, Wei et al., (2000) described this with leaf miners in various plant species; Peeters (2002) demonstrated the negative correlation between leaf structures and herbivory; and Lazzari & Zonta-de-Carvalho (2013) depicted the host plant selection process by aphids, showing that factors such as distance, physical and chemical stimuli, lignin, fibers, phloem elements, among other stimuli, interfere with the insect's preference for certain plants.

Host plant resistance in maize involves strategies against various pests, including sap-sucking insects. The use of resistant genotypes and the understanding of plant-insect interactions are fundamental for effective pest management (Soujanya et al., 2024). These predictive resistance characteristics are expressed throughout the crop cycle and are linked to the genetic constitution of the cultivar. Therefore, Souza et al., (2021) state that the form of resistance expression is constitutive and allopatric, where the pest insect did not interfere in the evolution of the plant species' characteristics. The study of natural plant resistance is of utmost importance and an important component in IPM (Integrated Pest Management).

The results discussed above corroborate research conducted by Pascutti et al., (2021) with the green-belly stink bug, where these authors observed a significant difference in plant height in the presence of the pest insect compared to its absence, with a height reduction exceeding 23%.

By analyzing the phenological stage, stem diameter, and plant height of the 35 maize cultivars analyzed (Table 1), it can be inferred that 16 genotypes (1P2206, 1Q2366, 1Q2400, 1Q2425, 1Q2427, 1Q2473, 1R2620, 1S2747, 2R2642, 3S2734, 3S2755, 3S2761, 3S2787, BRS1055, BRS3042, BRS3042VTPRO2) showed the highest resistance to the green-belly stink bug in the present experiment. Adding the injury score variable from the second experiment, it can be inferred that five hybrids (2R2642, 1Q2425, 1R2536, 1P2206VTPRO2, 3S2761) showed the greatest resistance. These results highlight the interrelationship between morphological and phenological parameters, evidencing the mutual influence between growth and resistance of the hybrids.

The joint analysis of the results from Figures 1, 2, and 3, and Tables 1 and 2 indicate that in maize breeding programs, the characteristics phenological stage, stem diameter, and plant height can be predictors of maize plant resistance to the green-belly stink bug, eliminating the need for infestation trials. Therefore, these characteristics can be parameters for selection and incorporation into elite maize germplasm, aiming at resistance to *Diceraeus melacanthus* (Moawad, 2014), and also indicative of cultivars more likely to be resistant to the pest, reducing research effort and accelerating the achievement of results and resistant genotypes.

CONCLUSION

I - The parameters phenological stage, stem diameter, and plant height have proven to be effective characteristics related to reducing the injury score caused by the green-belly stink bug, representing important parameters for pest management in the field as the plant grows and develops, and for selection and incorporation into maize cultivars aimed at resistance to *Diceraeus spp*.

II – Based on the parameters phenological stage, stem diameter, and plant height, 16 genotypes from the first trial (1P2206, 1Q2366, 1Q2400, 1Q2425, 1Q2427, 1Q2473, 1R2620, 1S2747, 2R2642, 3S2734, 3S2755, 3S2761, 3S2787, BRS1055, BRS3042, BRS3042VTPRO2) showed higher resistance to the green-belly stink bug in the present experiment, and another five hybrids in the second trial (2R2642, 1Q2425, 1R2536, 1P2206VTPRO2, 3S2761) are candidates for advancement and use as sources of resistance to the green-belly stink bug.

The selection of predictive resistance characteristics in plants is an efficient strategy to identify resistant genotypes, making the process more accessible, operationally simple, and less dependent on bioassays, which are difficult to apply on a large scale in breeding programs.

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CONTRIBUTION OF EACH AUTHOR

N.M. dos Santos: investigation (equal); methodology (equal) and writing (equal). M.A.M. Fadini: editing and review (equal). R.D.S. Trindade: review, methodology, and resources (equal). P.F. Lima: methodology (equal). G.S. de Avellar: methodology (equal). D.G. dos Santos: methodology (equal). B.L.S. Silva: editing and review (equal). S.M. Mendes: methodology, review, and editing (equal); funding acquisition (equal); project and laboratory administration (equal); resources (equal).

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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