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MINERAL NUTRIENT AND CRUDE SILICA RESPONSES OF RICE GERMPLASM TO BROWN PLANTHOPPER, *Nilaparvata lugens* (STAL) INFESTATION

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ABSTRACT

The present study assessed germplasm accession-dependent changes in nitrogen, phosphorus, potassium and crude silica concentrations following brown planthopper, *Nilaparvata lugens* (Stal) infestation in twelve rice germplasm accessions with contrasting levels of resistance, along with the resistant check PTB 33 and susceptible check TN 1. Thirty-day-old plants were infested with ten second- to third-instar nymphs per plant, and leaf sheath samples were collected seven days after infestation. The concentrations of nitrogen, phosphorus, potassium and crude silica were quantified using standard analytical procedures under a completely randomized design with three replications. Significant differences among accessions were observed for all four nutritional components under both uninfested and infested conditions. Nitrogen exhibited the greatest infestation-associated variation, increasing by 5.76% in TGC 108 and 5.48% in UN 46 22K, whereas the susceptible check TN 1 exhibited the largest reduction (46.49%), followed by the susceptible accessions TGC 1 (44.00%) and TGC 14 (41.08%). Phosphorus generally declined following infestation, with minimal reductions in the resistant check PTB 33 (0.23%) and TGC 108 (6.02%), whereas the susceptible accession TGC 14 and susceptible check TN 1 exhibited pronounced reductions of 31.77% and 29.93%, respectively. Potassium declined across all accessions, with the smallest reductions in TGC 108 (1.16%) and the moderately resistant TGC 62 (2.59%), whereas the susceptible accession TGC 88 showed the greatest reduction (30.51%) and TN 1 showed a 16.77% reduction. In contrast, crude silica increased in PTB 33 (8.86%), TGC 108 (7.50%) and UN 46 22K (16.01%), while it declined in the susceptible check TN 1 (17.95%) and susceptible accessions TGC 66 (37.48%) and TGC 88 (17.65%). Notably, increased crude silica was also observed in moderately resistant accessions, including TGC 62 (8.37%) and TGC 13 (12.83%), despite substantial depletion of selected mineral nutrients in the latter. Overall, resistant germplasm exhibited greater stability of mineral nutrient concentrations and increased crude silica following BPH infestation, whereas the susceptible test entries as well as the susceptible check showed pronounced depletion of measured components. However, no single nutrient consistently differentiated the resistance categories, indicating that BPH resistance was associated with a genotype-specific combination of nutritional homeostasis and silica-related structural reinforcement rather than a single nutritional trait.

***Key words*: *Nilaparvata lugens*; host plant resistance; mineral nutrition; silicon; structural defence**

Introduction

Rice (*Oryza sativa* L.) is a major staple crop supporting more than half of the global population, particularly in Asia (Kumari and Nair, 2023). However, rice production is persistently threatened by insect pests, with the brown planthopper (BPH), *Nilaparvata lugens*

(Stal) (Hemiptera: Delphacidae), recognised as one of the most destructive pests affecting rice cultivation in major rice-growing regions. This oligophagous phloem feeder infests both the vegetative and reproductive stages of rice (Sukumar *et al*., 2022). The sustained feeding of BPH nymphs and adults impairs phloem transport and assimilate translocation, resulting in reduced tillering, stunted growth, leaf chlorosis, and, under severe infestation, the characteristic hopper-burn symptom, with yield losses reaching up to 20–80% (Watanabe and Kitagawa, 2000; Sriram *et al*., 2024). In addition to direct feeding injury, BPH serves as a vector of rice grassy stunt virus and rice ragged stunt virus, further exacerbating crop losses (Cabauatan *et al*., 2009). The substantial economic losses associated with BPH infestation have consequently stimulated extensive research into the physiological and biochemical mechanisms underlying rice–BPH interactions, with plant nutritional status emerging as an important determinant of host suitability.

The availability and balance of essential mineral nutrients can substantially influence rice-BPH interactions. Among these, nitrogen (N), phosphorus (P), and potassium (K) are particularly important owing to their contributions to plant metabolism and defence. Nitrogen availability strongly influences phloem nutritional quality through its effects on amino acids and soluble proteins, with increased N supply generally enhancing host nutritional value and potentially favouring BPH growth and reproduction, whereas N deficiency may induce metabolic changes that reduce host suitability (Lu *et al*., 2004; Rashid *et al*., 2017). Phosphorus contributes primarily to energy metabolism, nucleic acid synthesis, and membrane function, thereby supporting growth and defence, although its effects on herbivore performance are generally less pronounced than those associated with N (Vance *et al*., 2003). Potassium, in turn, contributes to plant defence through its roles in physiological and metabolic regulation, with adequate K nutrition being associated with reduced insect infestation and altered nutritional suitability of host tissues (Mohapatra *et al*., 2018).

In addition to these macronutrients, silicon (Si), deposited as hydrated silica in rice tissues, has been recognized as a beneficial element contributing to resistance against insect herbivores through both physical reinforcement and the activation of defence-related pathways. Silica deposition strengthens epidermal tissues and can reduce feeding efficiency by herbivores, while Si-mediated signalling may further enhance inducible defence responses following herbivore attack (Keeping and Meyer, 2006; Reynolds *et al*., 2009). Accordingly, variation in the concentrations of N, P, K, and silica among rice genotypes may contribute to differences in host responses to BPH infestation and thus influence host suitability and resistance (Vanitha *et al*., 2011).

Although the effects of fertilizer management on BPH population dynamics have been extensively studied, the role of inherent differences in nutrient composition among rice germplasm with contrasting resistance levels, particularly following BPH infestation, remains comparatively underexplored. Therefore, the present study aimed to quantify the changes in nitrogen, phosphorus, potassium, and crude silica contents in selected rice germplasm before and after BPH infestation and to determine their association with differential resistance responses to BPH.

Materials and methods

Plant material and insect culture

Twelve rice germplasm accessions exhibiting contrasting levels of resistance to BPH, as reported by Sushma (2023), were selected for mineral nutrient characterisation. The selected accessions comprised TGC 108 (highly resistant); UN 46-22K (resistant); TGC 109, UN 55-22K, UN 43, TGC 13, and TGC 62 (moderately resistant); and TGC 14, TGC 66, TGC 88, TGC 1, and TGC 15 (susceptible). The resistant check, PTB 33, and the susceptible check, TN 1, were also included in the study. Seeds of the selected germplasm accessions were obtained from the Department of Seed Science and Technology, College of Agriculture, Kerala Agricultural University, Thrissur, Kerala, India. The susceptible check (TN 1) was obtained from the Department of Entomology, Indian Institute of Rice Research, Hyderabad, India and the resistant check (PTB 33) was procured from the Division of Entomology, Regional Agricultural Research Station, Pattambi, Kerala, India.

The initial population of unparasitized BPH was collected from rice fields of Palakkad, Kerala, India (10.73128° N, 76.399706° E) during October–November 2023. The insect colony was subsequently maintained on 40–50-day-old potted plants of the susceptible rice variety TN 1 under controlled laboratory conditions at 28 ± 2 °C and 70 ± 5% relative humidity. To maintain a continuous colony, 5–10 gravid females were periodically transferred from infested plants to fresh TN 1 plants at 30-day intervals, allowing the establishment of successive generations.

Mineral nutrient analysis

Mineral nutrient analysis was carried out in a completely randomized design with three replications.

Seeds were sown separately in two sets of pots. One set of 30-day-old plants was maintained without BPH infestation to assess the constitutive nutrient composition, while the other set of the same age was infested with ten second- to third-instar BPH nymphs per plant to evaluate infestation-induced changes in nutrient composition. Seven days after infestation, green leaf sheath samples were collected from BPH-infested plants for the estimation of nitrogen, phosphorus, potassium, and crude silica concentrations. The samples from control plants maintained without infestation were also collected on the same day for analysis.

The collected leaf sheath samples were initially shade-dried and subsequently oven-dried at 70°C in a hot air oven until a constant weight was attained. The dried samples were finely powdered using a mechanical grinder, and the powdered material was stored in airtight containers until further analysis. The prepared samples were used for the estimation of nitrogen, phosphorus, potassium, and crude silica contents following standard analytical procedures (Jackson, 1973).

Estimation of Nitrogen

Total nitrogen content of plant samples was estimated using the Kjeldahl method. Finely powdered dry plant material (0.2 g) was pre-digested with 10–15 mL concentrated H, SO_4, and 3 g digestion mixture (K_2SO_4: $CuSO_4$, 10:1 ratio) for 24 h, followed by digestion at 230°C with gradual temperature elevation to 400°C until complete digestion. The digest was cooled, diluted to 50 mL, and a10 mL aliquot was subjected to distillation using an Auto N Analyzer with 40% NaOH and 4% boric acid containing mixed indicator. The liberated ammonia was collected until 10 mL of distillate was obtained and titrated against 0.02 N H_2SO_4. A reagent blank was run simultaneously, and nitrogen content was calculated using the standard Kjeldahl equation.

Estimation of Phosphorus and Potassium

For phosphorus and potassium estimation, 0.2 g of finely powdered plant sample was digested with 10 mL of diacid mixture (HNO_3:$HClO_4$; 9:4 ratio). The samples were pre-digested overnight and heated at 230°C until a clear, colourless digest was obtained. The cooled digest was transferred to a 50 mL volumetric flask, made up to volume with distilled water, and filtered through Whatman No. 1 filter paper. The filtrate was used for nutrient estimation.

Phosphorus content was estimated by the vanadomolybdate (Barton's reagent) method using KH_2PO_4 as the standard. An aliquot of the plant digest was treated with Barton's reagent, and the absorbance was recorded at 475 nm after colour development. The phosphorus concentration was calculated from the standard curve and expressed as percentage.

Potassium content was estimated using a flame photometer using KCl as the standard. The diluted plant digest was used for potassium estimation, and the concentration was calculated from the standard curve and expressed as percentage.

Estimation of crude silica

Crude silica content was estimated following the acid digestion method (Yoshida *et al.*, 1976). An acid mixture containing concentrated nitric acid (HNO_3), sulphuric acid (H_2SO_4) and perchloric acid ($HClO_4$) in the ratio of 5:1:2 was prepared. One gram of oven-dried and finely ground plant sample was transferred to a 75 mL Pyrex test tube, and 10 mL of the acid mixture was added. The mixture was allowed to predigest for 2 h under a fume hood and was then heated gradually until a clear digest was obtained without evaporating to dryness. After cooling, the digest was made up to 50 mL with distilled water and filtered through acid-washed Whatman No. 44 ashless filter paper. The filtrate was used for nutrient analysis, while the filter paper containing the residue was retained for crude silica estimation.

The filter paper with the residue was dried in a hot air oven at 80°C, charred over a flame under a fume hood, and ashed in a muffle furnace at 550 °C for 2 h. The ash was cooled in a desiccator and weighed. The crude silica content was calculated using the following formula:

$$\text{Crude silica (\%)} = \frac{\text{Weight of crude silica (g)}}{\text{Weight of sample (g)}} \times 100$$

Statistical analysis

The data were analysed using one-way analysis of variance (ANOVA) under a completely randomized design (CRD) using the RASINS statistical package version 2.2.0. The treatment means were compared using Duncan's Multiple Range Test (DMRT) at a significance level of $p \leq 0.001$, and the results are presented as mean ± standard error.

Results and Discussion

The concentrations of nitrogen, phosphorus, potassium and crude silica varied significantly among rice germplasm accessions under both uninfested and BPH-infested conditions, with the magnitude of infestation-associated changes differing among germplasm accessions (Table 1; Fig. 1). In uninfested plants, N concentration ranged from 1.96% in PTB 33 to 3.85% in TGC 66. Following infestation, N increased by 5.76% in TGC 108 and 5.48%

Table 1: Nitrogen, phosphorus, potassium and crude silica concentration of rice germplasm before and after BPH infestation.

Germplasm accession	RC	Nitrogen (%)		Phosphorus (%)		Potassium (%)		Crude silica (%)	
		Uninfested	Infested	Uninfested	Infested	Uninfested	Infested	Uninfested	Infested
TGC 108	HR	2.38 ± 0.04^{j}	2.52 ± 0.03^{c}	0.23 ± 0.01^{e}	0.22 ± 0.01^{de}	2.65 ± 0.13^{cd}	2.62 ± 0.13^{ab}	12.00 ± 0.10^{c}	12.90 ± 0.10^{c}
UN 46 22K	R	3.71 ± 0.04^{c}	3.92 ± 0.04^{a}	0.34 ± 0.02^{a}	0.28 ± 0.02^{a}	2.98 ± 0.13^{b}	2.45 ± 0.14^{bc}	12.50 ± 0.10^{b}	14.50 ± 0.10^{b}
TGC 62	MR	2.61 ± 0.03^{i}	2.58 ± 0.07^{c}	0.35 ± 0.02^{a}	0.27 ± 0.02^{ab}	2.61 ± 0.13^{cd}	2.54 ± 0.13^{b}	6.00 ± 0.10^{g}	6.50 ± 0.10^{i}
UN 55 22K	MR	3.50 ± 0.03^{f}	2.73 ± 0.04^{b}	0.32 ± 0.02^{ab}	0.24 ± 0.01^{cd}	2.34 ± 0.13^{ef}	2.00 ± 0.06^{d}	10.10 ± 0.96^{d}	10.54 ± 1.09^{e}
TGC 109	MR	2.38 ± 0.03^{j}	1.75 ± 0.03^{i}	0.24 ± 0.01^{e}	0.18 ± 0.01^{f}	3.26 ± 0.14^{a}	2.81 ± 0.14^{a}	9.30 ± 0.10^{e}	10.01 ± 0.10^{ef}
TGC 13	MR	3.64 ± 0.04^{d}	2.17 ± 0.03^{e}	0.30 ± 0.02^{bc}	0.27 ± 0.02^{ab}	2.66 ± 0.13^{cd}	2.06 ± 0.13^{d}	10.10 ± 0.36^{d}	11.40 ± 0.60^{d}
UN 43	MR	2.80 ± 0.03^{h}	2.31 ± 0.03^{d}	0.26 ± 0.02^{de}	0.20 ± 0.00^{ef}	2.37 ± 0.12^{e}	1.89 ± 0.05^{d}	9.11 ± 0.10^{e}	9.53 ± 0.11^{f}
TGC 14	S	3.83 ± 0.04^{ab}	2.26 ± 0.04^{d}	0.28 ± 0.02^{cd}	0.19 ± 0.01^{ef}	2.08 ± 0.12^{g}	1.56 ± 0.12^{e}	8.50 ± 0.10^{f}	7.60 ± 0.10^{gh}
TGC 1	S	3.50 ± 0.04^{f}	1.96 ± 0.03^{g}	0.32 ± 0.02^{ab}	0.23 ± 0.03^{cd}	2.13 ± 0.13^{fg}	1.53 ± 0.12^{e}	5.20 ± 0.10^{h}	4.90 ± 0.10^{j}
TGC 15	S	3.32 ± 0.03^{g}	2.03 ± 0.03^{f}	0.34 ± 0.02^{a}	0.25 ± 0.01^{bc}	2.52 ± 0.13^{cde}	1.84 ± 0.12^{d}	9.00 ± 0.10^{e}	7.80 ± 0.10^{g}
TGC 66	S	3.85 ± 0.04^{a}	2.66 ± 0.03^{b}	0.29 ± 0.02^{bc}	0.20 ± 0.00^{ef}	2.42 ± 0.13^{de}	2.33 ± 0.06^{c}	8.00 ± 0.10^{f}	5.00 ± 0.10^{j}
TGC 88	S	3.78 ± 0.04^{b}	2.31 ± 0.04^{d}	0.34 ± 0.02^{a}	0.24 ± 0.01^{cd}	2.71 ± 0.13^{c}	1.88 ± 0.08^{d}	8.50 ± 0.10^{f}	7.00 ± 0.10^{hi}
PTB 33	RC	1.96 ± 0.03^{k}	1.83 ± 0.08^{h}	0.29 ± 0.02^{bc}	0.29 ± 0.02^{a}	2.70 ± 0.13^{c}	2.45 ± 0.14^{bc}	15.00 ± 0.30^{a}	16.33 ± 0.67^{a}
TN 1	SC	3.57 ± 0.04^{e}	1.91 ± 0.05^{g}	0.28 ± 0.01^{cd}	0.19 ± 0.01^{ef}	2.71 ± 0.13^{c}	2.26 ± 0.13^{c}	5.00 ± 0.10^{h}	4.10 ± 0.10^{k}
F stat		985.72**	519.07**	15.71**	17.91**	17.82**	35.77**	258.98**	275.99**
p value		0	0	0	0	0	0	0	0
SE(m)		0.02	0.02	0.01	0.01	0.07	0.07	0.17	0.22
CV(%)		1.1	1.77	5.61	6.46	4.96	5.3	3.26	4.23

RC: Resistance category; Values are expressed as mean ± SE. Means followed by different superscript letters differ significantly at P < 0.001 according to Duncan's Multiple Range Test (DMRT). HR- Highly resistant; R- Resistant; MR- Moderately resistant; S- Susceptible; RC- Resistant check; SC- Susceptible check

in UN 46 22K, whereas it was reduced in all the remaining accessions. The largest reductions in N concentration were observed in TN 1 (46.49%), TGC 1 (44.00%) and TGC 14 (41.08%), which had relatively high basal N concentrations of 3.57, 3.50 and 3.83%, respectively. In contrast, the resistant check PTB 33, with the lowest basal N concentration (1.96%), exhibited only a 6.65% reduction.

The relatively high basal N concentrations observed in several susceptible accessions are consistent with the established role of plant N status in determining the nutritional quality of plant tissues for herbivores. Nitrogen is a major constituent of amino acids and proteins and

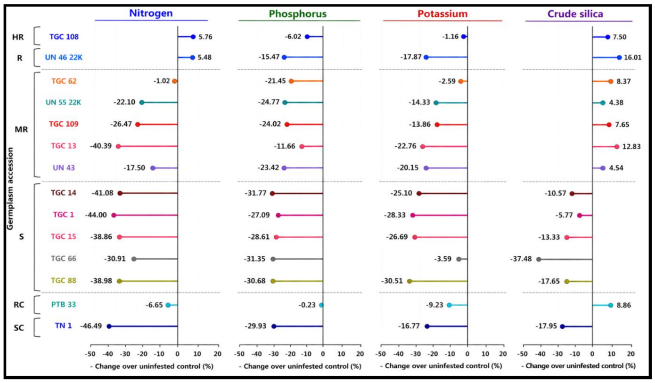


Fig. 1: Percentage change in nitrogen, phosphorus, potassium and crude silica concentration of rice germplasm following brown planthopper infestation relative to uninfested control.

contributes substantially to primary metabolism, thereby influencing the nutritional value of plant tissues to herbivores (Mattson, 1980). Increased N availability can further alter the abundance of N-containing metabolites and enhance herbivore performance (Sauge *et al.*, 2010). In rice, increased N availability has likewise been reported to enhance BPH damage and accelerate plant injury (Rashid *et al.*, 2016). However, the variation in basal N concentration among the accessions did not correspond consistently with their resistance levels. UN 46 22K had a relatively high basal N concentration of 3.71% but exhibited a 5.48% increase following infestation, whereas PTB 33 had the lowest basal N concentration (1.96%) and showed only a 6.65% reduction. In contrast, TN 1, with a basal N concentration of 3.57%, exhibited the largest reduction (46.49%). Thus, the magnitude of the infestation-associated change in N was not determined solely by basal N concentration. The comparatively limited alteration of N concentration in PTB 33, TGC 108 and UN 46 22K suggests a greater capacity to maintain N status under BPH infestation. In contrast, the pronounced reduction in TN 1 indicates greater alteration of N status. Genotypic differences in nutrient assimilation and utilization may contribute to such variation (Singh *et al.*, 1998).

Phosphorus showed a predominantly declining response following infestation, with reductions ranging from 0.23% to 31.77% across accessions. TGC 108

showed a 6.02% reduction, TGC 14 the greatest reduction (31.77%), whereas PTB 33 exhibited the smallest reduction in P concentration (0.23%). Phosphorus is involved in nucleic acid synthesis, energy transfer, membrane metabolism and cellular growth and may consequently influence plant physiological performance and insect nutritional requirements (Raghothama and Karthikeyan, 2005). Previous studies have demonstrated effects of P availability on insect fecundity, oviposition and reproductive investment (Huberty and Denno, 2006; Rashid *et al*., 2016). Nevertheless, basal P concentration did not correspond consistently with the resistance response in the present study. Interestingly, TGC 108, despite having the lowest basal P concentration (0.23%), exhibited only a 6.02% reduction following BPH infestation, whereas TGC 62, TGC 1 and TGC 14, with higher basal P concentrations of 0.35, 0.32 and 0.28%, respectively, showed considerably greater reductions. This contrasting response suggests that the extent of P depletion following infestation was not governed by the initial P status of the accessions. The near-maintenance of P in PTB 33, together with its limited depletion in TGC 108, further indicates genotype-dependent differences in the ability to maintain P status under BPH stress. Rashid *et al*., (2016) reported that the lack of a consistent association between P status and resistance may be attributed to the relatively limited influence of P fertilisation on BPH feeding and rice tolerance.

Potassium concentration declined following infestation in all accessions, although the magnitude of reduction varied substantially. TGC 108 and TGC 62 exhibited the smallest reductions (1.16 and 2.59%, respectively), whereas the greatest reductions were observed in TGC 88 (30.51%), TGC 1 (28.33%), TGC 15 (26.69%) and TGC 14 (25.10%). TN 1 showed a 16.77% reduction, while PTB 33 exhibited a comparatively smaller reduction of 9.23%. Potassium regulates numerous physiological processes, including enzyme activation, osmotic regulation, protein synthesis and carbohydrate metabolism, and has an established role in plant responses to biotic and abiotic stress (Amtmann and Armengaud, 2009; Wang *et al*., 2013). Potassium deficiency can modify carbohydrate and protein metabolism and increase the accumulation of soluble sugars and amino acids, thereby altering plant nutritional quality for herbivores (Amtmann *et al*., 2008). Basal K concentration did not correspond consistently with the magnitude of the infestation-associated response. TGC 109 had the highest basal K concentration (3.26%) but exhibited a 13.86% reduction, whereas TGC 108 had a lower basal concentration (2.65%) and showed only a reduction of 1.16%. The limited reduction in K in TGC 108, together with the relative stability of P and increase in N, suggests a greater capacity to maintain mineral nutrient status under BPH infestation. Such stability may contribute to the preservation of metabolic functions under BPH stress, although its direct contribution to resistance cannot be established from the present data.

Crude silica exhibited a distinct response pattern relative to the macronutrients. PTB 33 exhibited the highest basal crude silica concentration (15.00%), which increased to 16.33% following infestation, corresponding to an 8.86% increase. TGC 108 and UN 46 22K also exhibited increases of 7.50 and 16.01%, respectively. In contrast, TN 1, TGC 66 and TGC 88, with basal crude silica concentrations of 5.00, 8.00 and 8.50%, respectively, showed reductions of 17.95, 37.48 and 17.65% following infestation. Silicon accumulation can increase tissue rigidity and toughness, thereby strengthening the physical barrier to herbivore feeding and impeding stylet penetration and phloem access in piercing-sucking insects (Reynolds *et al*., 2009; Yang *et al*., 2017). The increased silica concentration in PTB 33, TGC 108 and UN 46 22K following infestation is consistent with a potential contribution of silica-associated structural reinforcement to BPH resistance. Conversely, the reduction in silica observed in TN 1 and several susceptible accessions indicates reduced maintenance of this structural component following infestation. Since the present study quantified crude silica rather than its spatial deposition or associated tissue mechanical properties, the observed association between silica status and resistance cannot establish a direct effect on stylet penetration.

The nutritional responses differed among resistant genotypes, indicating that resistance was not associated with a uniform nutritional phenotype. Such variation may reflect inherent genotypic differences in nutrient uptake, allocation and utilization, which are well documented in rice (Singh *et al*., 1998; Wissuwa and Ae, 2001). TGC 108 exhibited a 5.76% increase in N, limited reductions in P (6.02%) and K (1.16%), and a 7.50% increase in crude silica, reflecting comparatively greater mineral stability following infestation. In contrast, UN 46 22K showed a substantial reduction in K (17.87%) despite increases in N (5.48%) and crude silica (16.01%), suggesting that enhanced silica accumulation may contribute to resistance even when the stability of individual mineral nutrients is not maintained. PTB 33 exhibited comparatively small reductions in P and K (0.23% and 9.23%, respectively), while its already high basal crude silica concentration (15.00%) further increased to 16.33% following infestation. Thus, the

contrasting responses of these resistant genotypes highlight differences in the relative contribution of mineral nutrient stability and silica accumulation to their response to BPH infestation.

The absence of a consistent relationship between individual nutrient responses and resistance category was further evident in TGC 13 and TGC 62. TGC 62 exhibited only minor reductions in N (1.02%) and K (2.59%) and an 8.37% increase in crude silica, despite a substantial reduction in P (21.45%). In contrast, TGC 13 showed pronounced reductions in N (40.39%), P (11.66%) and K (22.76%), while crude silica increased by 12.83%. The increase in crude silica in these moderately resistant accessions, particularly TGC 13 despite substantial mineral nutrient depletion, suggests that silica-associated structural reinforcement may contribute to resistance even when mineral nutrient stability is not maintained. These contrasting responses indicate that no individual mineral component consistently explains resistance and that the resistance phenotype may instead involve interactions among nutrient status, nutritional stability and structural defence. Such interactions are consistent with the established role of mineral nutrition in regulating plant growth, primary metabolism and defence responses during plant–herbivore interactions (Amtmann *et al*., 2008) while mineral availability may also influence structural defences, defensive metabolite production and other plant traits determining host suitability to herbivores (Li *et al*., 2024). Silica-associated structural reinforcement may therefore operate alongside other resistance mechanisms, potentially including antixenosis and tolerance. However, these mechanisms cannot be inferred directly from the present nutrient and silica responses.

The contrasting responses of the resistant and susceptible checks further demonstrate differential nutritional stability following BPH infestation. TN 1 exhibited pronounced reductions in N (46.49%), P (29.93%), K (16.77%) and crude silica (17.95%), indicating substantial alteration across all measured components. In contrast, PTB 33 showed comparatively limited reductions in N (6.65%), P (0.23%) and K (9.23%), while crude silica increased by 8.86%. The marked contrast between the two checks further supports a genotype-dependent association between mineral nutrient stability, silica accumulation and BPH resistance.

Although comparison with the corresponding uninfested controls demonstrated infestation-associated changes in nutrient concentrations, the physiological processes underlying these changes cannot be resolved from the present study. The observed responses may reflect alterations in nutrient uptake, internal redistribution, tissue growth, water status and defence-associated resource allocation, in addition to possible nutrient losses associated with BPH feeding (Qiu *et al*., 2004; Schwachtje and Baldwin, 2013; Rashid *et al*., 2016). Differences in tissue biomass may also influence nutrient concentrations expressed on a tissue basis, highlighting the importance of considering nutrient concentrations alongside biomass accumulation and total nutrient uptake (Jarrell and Beverly, 1981). In addition, insect herbivory can alter primary metabolism and nutrient allocation within plants, making the interpretation of a single post-infestation measurement difficult (Zhou *et al*., 2015). Temporal measurements of nutrient uptake, redistribution and allocation, together with biochemical and physiological indicators of defence, would therefore be required to clarify the mechanisms underlying the observed changes (Zust and Agrawal, 2017).

Collectively, the results demonstrate substantial genotype-dependent variation in N, P, K and crude silica responses to BPH infestation. The contrasting patterns suggest that mineral nutrient stability and silica-associated structural reinforcement may contribute differently among genotypes to BPH resistance, while no individual mineral component alone adequately explains the observed resistance.

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