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Marta C. Filippi [a] & Anne S. Prabhu [a]
[a] National Rice and Bean Research Center , Embrapa-CNPAF , Caixa Postal 179, Goidnia, GO, CEP 74001-970, Brazil

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# Relationship Between Panicle Blast Severity and Mineral Nutrient Content of Plant Tissue in Upland Rice

**Marta C. Filippi and Anne S. Prabhu**

*National Rice and Bean Research Center, Embrapa-CNPAF, Caixa Postal 179,*
*CEP 74001-970, Goiânia, GO, Brazil*

## ABSTRACT

Panicle blast (*Pyricularia grisea*) in upland rice causes significant yield losses depending upon the environmental conditions and nutritional status of the plant at the grain-filling stage. Four field experiments were conducted to evaluate the influence of mineral nutrients on panicle blast of four upland rice genotypes on an oxisol. Panicle blast severities of four genotypes were related to nutrient concentrations in panicle tissues. Nitrogen (N), phosphorus (P), and magnesium (Mg) contents in tissue were significantly ($P<0.01$) and positively correlated, whereas potassium (K) and calcium (Ca) were negatively correlated with panicle blast severity. While the relationship between tissue N concentration and disease severity was quadratic, it was linear for K concentration. The correlation between tissue contents of N and P were positive and highly significant ($r=0.75$ $P<0.001$). Micronutrient tissue concentrations were not significantly correlated to panicle blast severities except for zinc (Zn). The low panicle blast severities of improved cultivar Guarani were associated with high K and Zn and low N, P, and Mg tissue concentrations.

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## INTRODUCTION

Panicle blast [*Pyricularia grisea* (Cooke) Saccardo] in upland rice is responsible for greater yield reductions than leaf blast in central Brazil. Neck or panicle blast occurs 7 to 10 days after heading and continues to increase until maturity affecting grain filling and grain weight. Loss in grain weight was reported to be 38% when panicles were infected at the milk stage (Prabhu and Faria, 1982), and panicle blast, 25 days after heading, accounted for variations in grain yield in most upland rice cultivars (Prabhu et al., 1989). There is yet no reliable method of predicting panicle blast incidence, which depends upon specific weather conditions and nutritional status of the plant. Intermittent drought and prolonged periods of dew have been known to predispose the plants to severe panicle blast. Plants subjected to water stress during panicle emergence showed high percentage of N in different parts of the plant in upland rice cultivar IAC 47 (Stone et al., 1979). Varietal differences in N and P utilization have been reported in studies with upland rice cultivars (Fageria et al., 1988). Balanced nutrition has an important role in determining plant resistance or susceptibility to diseases. Excessive N fertilization increases susceptibility of plants to obligate pathogens and resistance to facultative parasites (Kiraly, 1976; Huber, 1980; Fageria et al., 1991). The time of application and amount of N fertilizer has pronounced effect on blast (Huber, 1980). Potassium amendments have been known to increase or decrease blast severity (Kozaka, 1965). Earlier studies were conducted mostly on the effect of nutrients on leaf blast development in irrigated ecosystem and panicle blast did not receive adequate attention. In Brazil, investigations under upland conditions showed that increased doses of N favored both leaf and panicle blast (Faria et al., 1982; Santos et al., 1986). When phosphate was not limiting, excessive doses of P increased panicle blast severity in upland rice (Prabhu and Morais, 1986).

Panicle blast development has known to be influenced by general vigor and host plant nutrition. Tissue concentration of mineral elements in resistant and susceptible cultivars determine the disease severity. The silica content in tissues was related to susceptibility of rice to blast (Marschner, 1986). There is no information on panicle tissue analysis to correlate the effect of nutrients on the panicle blast development. The knowledge on the role of major and minor elements in increasing or decreasing panicle blast severity is important for disease management.

The objective of the present investigation was to study the relation between mineral nutrient content in panicle tissue and panicle blast severity in upland rice.

## MATERIALS AND METHODS

Four field experiments were conducted, one in 1987-88 and three in 1988-89 rice growing seasons, at the National Rice and Bean Research Center (CNPAF-embrapa), Goiânia, GO, Brazil. The soil at the experimental site was Dark Red Latosol according to the Brazilian Classification System which is equivalent to an oxisol in the U.S.A. soil taxonomy. The soil analysis used in these experiments showed the following characteristics: pH=5.2; extractable P=1.5 mg $kg^{-1}$; and extractable cations were K=3.6 mg $kg^{-1}$; Ca + Mg=2.6 cmol $kg^{-1}$ and Al=0.2 cmol $kg^{-1}$. All the four experiments were conducted in the adjoining areas. The treatments totaling eight consisted of seed treated with pyroquilon and seed untreated for early maturing genotypes. The genotypes included two traditional cultivars (IAC 165, IAC 25), improved rice cultivar (Guarani) and an advanced breeding line (CNA 4136). They exhibit different degree of susceptibility to both leaf and panicle blast.

In the first year (Experiment 1), a randomized complete block design with three replications was used. The treatments were arranged in a split-plot scheme. Main plot treatments consisted of seed treated with fungicide pyroquilon (400 g, a.i., 100 $kg^{-1}$ of seed) and seed untreated. The subplots included four rice genotypes. Main plot treatments and subplot treatments within main plots were randomized and replicated twice. Seeds were drill planted on November 26, 1987.

Each subplot consisted of 30 rows, 15.0 m long and spaced 0.50 m. Four spreader rows with a mixture of susceptible cultivars were seeded on all four sides of the main plot. Main plots of seed treated and untreated were separated by three buffer rows of the resistant cultivar Três Marias. Both spreader and buffer rows were established 30 days before planting.

Plots were fertilized at planting with 200 kg $ha^{-1}$ (5-30-15+Zn) of NPK in addition to 50 kg $ha^{-1}$ of N in the form of ammonium sulfate and 20 kg $ha^{-1}$ of Zn sulfate. Seeds were sown at the rate of 40 kg $ha^{-1}$ in all experiments.

In the second year, three field experiments (Experiment 2, Experiment 3, and Experiment 4) were planted at different dates (November 10, November 20, and December 16, 1988) to obtain varying disease levels. A randomized complete block design with six replications was used.

Genotypes were assigned to main plots whereas subplots consisted of seed treatments. Each subplot included 6 rows, 6.0 m. long and spaced 0.50 m. Three spreader rows with a mixture of susceptible cultivars were sown on all four sides of the experiment. The rates and forms of fertilizer application were the same as in Experiment 1.

Four half meter observational row units, one each in central four rows, were demarcated for panicle blast evaluation. All panicles in each one of the four observational row units were assessed using a 5 grade scale (0, 5, 25, 50, 75, and 100% infected spikelets/panicle). The mean percentage of panicle blast severity (PBS) was calculated based on 200 panicles per treatment. Serial observations were made at 3 to 4 day intervals, 87, 90, 94, 97, and 101 days after sowing (DAS) in Experiment 2; 87, 91, 94, 98, 101, and 105 DAS in Experiment 3; and 90, 94, 97, and 101 DAS in Experiment 4. The logic [log Y/(1-Y)] of proportion of leaf blast severity was regressed on time in days according to Van Der Plank (1963), to estimate the apparent infection rate "b" (slope of the regression line).

All panicles that had 75% panicle emergence were pre-tagged and sampled 20 days after the panicle emergence. Fifty panicles were harvested per plot in the central four rows of each subplot, dried at 70°C to constant weight and milled. Ground material was digested with a mixture of nitric and percloric acids (2:1). The total N and P in the plant material was determined colorimetrically using a Tecator 1016 digester 1004 distilling unit, and all other elements were determined by atomic absorption spectroscopy (Moraes and Rabelo, 1986).

The variable panicle blast severities obtained in response to treatments were used to establish relationship between different mineral nutrient contents in plant tissue to panicle blast severities.

Data were subjected to standard ANOVA and linear and polygonal regression procedures for macro and micronutrients. A combined analysis of variance was performed for the three experiments conducted in 1988-89. Means were tested for significance using Tukey's test at the 0.05 probability level. Percentage of panicle blast severity were transformed to logits and plotted against time to calculate apparent infection rates according to Van Der Plank (1963).

## RESULTS AND DISCUSSION

Panicle blast severity was variable in different plots as a result of seed treatment and genotypic differences in the degree of susceptibility. Disease started 7 to 10 days after heading corresponding to 87 days after sowing and progressed until maturity in all experiments but differed in the rate at which the panicle blast developed. Apparent infection rate was relatively higher in experiment 4 compared to the other experiments (Figure 1). The terminal PBS 101 DAS for Experiments 1, 2, 3, and 4 were 16.87%, 12.75%, 25.74%, and 22.70%, respectively.

Highly significant differences ($P<0.01$) were observed among genotypes for panicle blast and macronutrients but the interaction seed treatment x cultivar was not significant in all experiments. Tissue nutrient concentration and panicle blast severities 101 DAS for all genotypes are shown in Table 1. Nutrient contents varied according to the genotype. Panicle blast severity of cultivar Guarani was significantly lower as compared to that exhibited by traditional rice cultivars IAC 165 and IAC 25 in Experiments 2 and 4. The significant low disease levels of Guarani may be related to the lower tissue N concentration observed in Experiment 4. Although panicle blast severity and the corresponding N levels in the tissues was not statistically significant in the other experiments, it was relatively lower for Guarani indicating a possible role of high phenolic content in decreasing panicle blast severity. Phenolic content of N deficient plants is high and the fungistatic effects decrease when N supply is high (Kiraly, 1976). The advanced line CNA 4136, which showed low panicle blast susceptibility, had exhibited relatively low tissue N concentration.

Similar relationship as in the case of N was obtained for P content in panicle tissue. The low disease severities of Guarani were associated with low P content

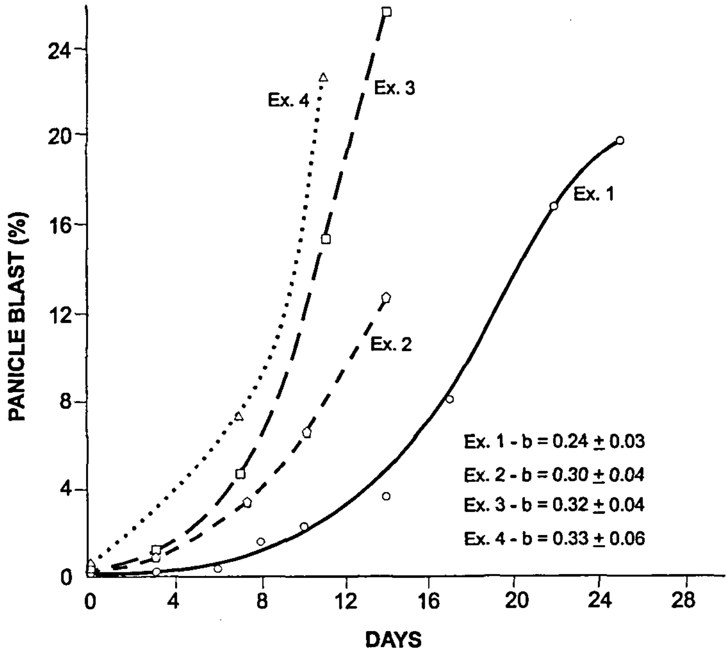

FIGURE 1. Panicle blast progress curves (percentages were based on average of four upland rice cultivars; Experiment 1, 0-81 DAS; Experiment 2, 0-87 DAS; Experiment 3, 0-87 DAS; Experiment 4, 0-90 DAS).

in the plant tissue in three experiments (Table 1). Phosphorus fertilization may decrease blast severity when this nutrient is limiting (Ou, 1985) or increase when doses are excessive without concomitant increase of other nutrients (Prabhu and Morais, 1986). According to Huber (1990) phosphorus reduces disease by promoting a mechanical barrier to pathogen penetration. However, it is not known if it applies to panicle blast severities of Guarani, which requires a more detailed investigation.

Genotypic differences in K content were also evident in all experiments. The significant low panicle blast severities of Guarani in Experiments 2 and 4 were associated with relatively higher K content in tissues. Low panicle blast severities obtained for Guarani and CNA 4136 had shown correspondingly lower Mg content in Experiments 2 and 4 (Table 2).

The cultivar Guarani which exhibited the lowest panicle blast severities had relatively higher Ca content than the other genotypes. Results in relation to tissue Zn content were not consistent in experiments for cultivar Guarani. Significant

TABLE 1. Panicle tissue nutrient contents and panicle blast severities in four upand rice cultivars. Means followed by the same letter in a column by experiment do not differ significantly according to Tukey's test at the probability level P=0.05.

| Experiment | | N | P | K | Ca | Mg | Zn | PBS(%) |
|---|---|---|---|---|---|---|---|---|
| | Cultivar | (g kg$^{-1}$) | (g kg$^{-1}$) | (g kg$^{-1}$) | (g kg$^{-1}$) | (g kg$^{-1}$) | (mg kg$^{-1}$) | |
| 1 | IAC165 | 0.91 c | 0.08 a | 1.67 a | 0.09 a | 0.13 a | 57.8 a | 15.5 a |
| | IAC-25 | 1.0 1ab | 0.09 a | 1.65 a | 0.10 a | 0.16 a | 50.2 a | 20.8 a |
| | Guarani | 0.94 bc | 0.09 a | 1.65 a | 0.11 a | 0.13 a | 47.2 a | 14.1 a |
| | CNA4136 | 1.10 a | 0.09 a | 1.35 b | 0.10 a | 0.15 a | 60.5 a | 17.0 a |
| | Mean | 0.99 | 0.09 | 1.58 | 0.10 | 0.14 | 53.9 | 16.9 |
| 2 | IAC165 | 0.91 a | 0.08 a | 1.48 ab | 0.10 a | 0.10 a | 32.8 b | 17.7 a |
| | IAC 25 | 0.87 a | 0.07 a | 1.44 b | 0.11 a | 0.10 a | 32.8 b | 17.1 a |
| | Guarani | 0.80 a | 0.06 b | 1.64 a | 0.11 a | 0.07 b | 40.7 a | 6.1 b |
| | CNA4136 | 0.84 a | 0.07 ab | 1.34 b | 0.10 a | 0.08 b | 37.2 ab | 10.2 b |
| | Mean | 0.86 | 0.07 | 1.48 | 0.11 | 0.09 | 35.9 | 12.8 |
| 3 | IAC165 | 0.91 a | 0.07 a | 1.42 bc | 0.07 a | 0.12 a | 38.0 a | 33.5 a |
| | IAC 25 | 0.86 a | 0.06 ab | 1.57 ab | 0.07 a | 0.10 b | 39.3 a | 22.4 a |
| | Guarani | 0.78 b | 0.06 b | 1.61 a | 0.07 a | 0.07 c | 36.5 a | 19.9 a |
| | CNA4136 | 0.85 ab | 0.06 ab | 1.34 c | 0.06 a | 0.09 b | 39.6 a | 27.2 a |
| | Mean | 0.85 | 0.06 | 1.49 | 0.07 | 0.10 | 38.4 | 25.8 |
| 4 | IAC165 | 0.91 a | 0.07 a | 1.44 a | 0.06 b | 0.12 a | 29.1 ab | 29.4 a |
| | IAC 25 | 0.90 a | 0.07 a | 1.33 ab | 0.08 a | 0.11 ab | 22.8 b | 24.1 a |
| | Guarani | 0.74 b | 0.05 b | 1.46 a | 0.08 a | 0.10 b | 28.9 ab | 14.3 b |
| | CNA4136 | 0.85 a | 0.06 a | 1.22 b | 0.07 b | 0.10 b | 30.3 a | 23.1 ab |
| | Mean | 0.85 | 0.06 | 1.36 | 0.07 | 0.11 | 27.8 | 22.7 |

differences among genotypes for other micronutrients such as iron (Fe), copper (Cu), sodium (Na), and manganese (Mn) were not obtained.

The mean nutrient contents of different genotypes in decreasing order were K, N, Mg, Ca, P, and Zn. These results are in agreement with those obtained by Malavolta and Fornasieri Filho (1983) except for Ca. Tissue nutrient levels, however were considerably lower than nutrient levels reported earlier due to differences in plant parts analyzed and cultivars. On whole plant basis, rice cultivars accumulate a greater amount of K followed by N and P (Fageria et al., 1991). The levels reported here are those for panicle branches after removing the grains, 10 days before harvest, when mineral content is usually low.

The combined analysis of the three experiments conducted in 1988/89 for individual mineral nutrients demonstrated highly significant differences among genotypes for N, P, K, Ca, Mg, and Zn content. The low panicle blast severities of Guarani were associated with high K and Zn and low N, P, and Mg concentrations

TABLE 2. Combined analysis of three experiments for macro and micronutrients. *Means followed by the same letter do not differ significantly* according to Tukey's test at the probability level P=0.05.

| Genotype | N<br>(g kg$^{-1}$) | P<br>(g kg$^{-1}$) | K<br>(g kg$^{-1}$) | Ca<br>(g kg$^{-1}$) | Mg<br>(g kg$^{-1}$) | Zn<br>(mg kg$^{-1}$) |
|---|---|---|---|---|---|---|
| IAC-165 | 0.91a | 0.07a | 1.45b | 0.08ab | 0.11a | 33.3ab |
| IAC-25 | 0.88a | 0.07ab | 1.45b | 0.08a | 0.10b | 31.7 b |
| Guarani | 0.77b | 0.06c | 1.58a | 0.09a | 0.08d | 35.4a |
| CNA4136 | 0.85a | 0.07b | 1.30c | 0.06b | 0.09c | 35.7a |

in panicle tissues (Table 2). The relationship of individual nutrient contents with high and low panicle blast severities only elucidate their possible role without taking into consideration the interrelationships among the nutrients. The rapid plant growth with a reasonable degree of resistance to panicle blast, as in the case of cultivar Guarani, may cause decrease in nutrient content which is referred to as dilution effect and requires further studies.

Simple correlation coefficients between mean panicle blast severity across genotypes and their tissue nutrient contents are shown in Table 3. Nitrogen concentration in the tissue in samples collected 20 days after heading was positively correlated with panicle blast severities at 97 and 101 DAS in three of the four experiments. Phosphorus showed similar positive correlations except in Experiment 1. Furthermore, the correlation between panicle blast and Mg was consistently positive and significant in all experiments at 101 DAS. Panicle blast severities were

TABLE 3. Correlation coefficents (r) of panicle blast severities with panicle tissue concentrations of macro nutrients.[a]

| Nutrients | Experiment 1 | | Experiment 2 | | Experiment 3 | | Experiment 4 | |
|---|---|---|---|---|---|---|---|---|
| | 97DAS | 101DAS | 97DAS | 101DAS | 97DAS | 101DAS | 97DAS | 101DAS |
| Nitrogen | 0.35 | 0.42*[b] | 0.16 | 0.20 | 0.52** | 0.47** | 0.40** | 0.36* |
| Phosphorus | 0.30 | 0.38 | 0.30* | 0.27 | 0.49** | 0.45** | 0.54** | 0.57** |
| Potassium | -0.27 | -0.33 | -0.32* | -0.31* | -0.18 | -0.21 | -0.25 | -0.14 |
| Calcium | -0.63** | -0.59** | -0.14 | -0.11 | -0.35* | -0.40** | -0.11 | -0.19 |
| Magnesium | 0.26 | 0.43* | 0.41** | 0.43** | 0.49** | 0.53** | 0.22 | 0.42** |

[a] Panicle were sampled 20 days after panicle emergence for nutrient analysis to correlate with panicle blast severities 97 and 101 days after sowing (DAS).

[b] r values followed by astirsks * and ** indicate significance at P=0.05 and P=0.01 probability levels, respectively.

TABLE 4. Correlation coeffecients (r) among panicle tissue concentration of macro and micro nutrients (Experiment 3).[a]

| Nutrients | Phosphorus | Calcium | Magnesium | Manganese | Iron |
|---|---|---|---|---|---|
| Nitrogen | 0.75**[b] | -0.48** | 0.58** | | -0.29* |
| *Phosphorus* | | -0.47** | 0.51** | | - |
| | | | | | 0.29* |
| Potassium | | | -0.34* | -0.37** | |
| Zinc | | -0.33* | | | |
| Magnesium | | | | 0.38** | |

[a] The number of observations in the analysis n=48.

[b] r values followed by asterisks * and ** indicate significance at the probability levels P = 0.05 and P = 0.01, respectiveley.

negatively correlated with K and Ca in all experiments but were statistically significant in two of them for Ca and in one for K, in samples collected both at 97 and 101 DAS.

The significant correlation coefficients among macro and some micronutrients in Experiment 3 are shown in Table 4. A high correlation between N and P contents in the tissue was obtained but it is not known how far it contributed to the PBS. Both these elements, associated with increased panicle blast severity (Table 3), were negatively correlated with Ca concentration. Calcium is applied in the form of lime-stone to cerrado soils to raise the pH and its role on disease development is related to the uptake of other elements. There was a negative correlation between Ca and Zn. Liming cerrado soils is known to cause Zn deficiency in rice (Fageria et al., 1991) and has been the general observation that leaves showing zinc deficiency symptoms had less blast (Prabhu and Morais, 1986). Application of calcium silicate slag has been shown to reduce blast from 15 to 32% (Datnoff et al., 1992). Calcium application is believed to reduce disease by reducing the maceration of middle lamella by extracellular enzymes that are produced by plant pathogen (Huber, 1980).

The positive correlation of Mg to N, P, and Mn, and negative correlation to K possibly demonstrate its effect in increasing panicle blast severity. The concentration of Fe in the panicle tissue was not significantly correlated to panicle blast severities in this study but it was negatively correlated with N and P which promoted blast disease. There is very little information on the effect of Fe on blast disease incidence and severity.

Tissue concentration of Mn was negatively correlated to K and positively to Mg. Although, correlation between Mn and panicle blast severity in this study was not significant, it may have an indirect effect on K and Mg content resulting in increased blast severity. Association between Mn concentration and leaf blast

TABLE 5. Regression equations relating panicle blast severity to mineral nutrient contents in plant tissue.

| Nutrients | Experiment | Equation[a] | r values[b] |
|---|---|---|---|
| Nitrogen | 1 | $Y= -80,91+159,64X-61,02X^2$ | 0.44* |
| | 2 | $Y= -57,92+139,16X-64,04X^2$ | 0.21* |
| | 3 | $Y=46,52-120,41X+111,66X^2$ | 0.49* |
| | 4 | $Y=-18,47+65,45X-19,57X^2$ | 0.37* |
| Phosphorus | 1 | $Y=-11,18+316,09X$ | 0.38* |
| | 2 | $Y=3,78+124,84X$ | 0.27* |
| | 3 | $Y=-13,60+624,23X$ | 0.45* |
| | 4 | $Y=-10,19+535,37X$ | 0.57* |
| Potassium | 1 | $Y=44,45-17,46X$ | -0.33* |
| | 2 | $Y=33,62-14,13X$ | -0.31* |
| | 3 | $Y=51,12-17,15X$ | -0.21 |
| | 4 | $Y=33,43-7,84X$ | -0.14 |
| Calcium | 1 | $Y=54,04-382,78X$ | -0.59* |
| | 2 | $Y=15,42-25,69X$ | -0.11 |
| | 3 | $Y=60,60-528,79X$ | -0.41* |
| | 4 | $Y=33,85-158,15X$ | 0.16 |
| Magnesium | 1 | $Y=-7,98+178,59X$ | -0.43* |
| | 2 | $Y=-5,73+212,70X$ | 0.43* |
| | 3 | $Y=-6,44+351,99X$ | 0.53* |
| | 4 | $Y=-8,79+292,50X$ | 0.42* |

[a] Y = Panicle blast; the disease observations made 101 DAS were utilized in adjusting the regression equations.

[b] r values followed by asterisks are significant at the probability level, P=0.05.

was reported by Osuna-Canizales et al. (1991) and Kürschner et al. (1992). The greater resistance observed in irrigated rice cultivars to blast as compared to that of upland rice has been attributed to the increased Mn uptake under flooded conditions (Chou and Chiou, 1979; Choong-Hoe, 1986). Manganese may be involved in disease development either by directly affecting pathogen virulence or by modifying host plant resistance (Huber, 1980).

Regression equations relating average panicle blast severities and tissue nutrient contents are shown in Table 5. A quadratic equation described the relationship between panicle blast and tissue N contents. These results indicate that N content is important up to certain level, above which panicle blast infection depends not only on N, but also other factors. High N concentration increases panicle blast severity and the dilution effect on other important nutrients, such as Ca and K, possibly explains the quadratic response. A linear positive relationship for P and Mg and negative for K and Ca explains a greater part of variation in the panicle blast severity. Potassium has been known to decrease susceptibility of plants to diseases and especially rice blast. However, this effect is confined to a deficiency range, and beyond optimal K supply no further increase in resistance can be achieved (Marschner, 1986). In the deficiency range, increased K supply leads to a non specific decrease in Ca and Mg contents (Marschner, 1986) which explain the low panicle blast severities.

Further investigations, however, are required under controlled greenhouse conditions to determine the role of major and minor elements on panicle blast.

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