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Effect of Mineral Nutrition and Abiotic Stress on Rice Stem Rot caused by *Sclerotium oryzae* Catt.

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ABSTRACT

Stem rot of rice caused by *Sclerotium oryzae* (Catt.) is an emerging disease with a potential to cause significant yield loses. An attempt was made to know the effect of mineral nutrition and abiotic stress is on the stem rot development under artificial inoculated conditions. Among the mineral nutrition applied, treatment T8 i.e., N+P+K+Zn+Fe (Recommended dosage of fertilizers (RDF)) had recorded the lowest mean per cent disease index of 18.52 with 55.88 per cent disease reduction over control at 66DAS, which indicated minor role of mineral nutrients in disease development. The highest PDI (39.51) with 429.22 AUDPC units^2 was recorded in the treatment T5 which received no potassium fertilization. There was no significant difference between treatments T2 receiving 2 x RDF NPK (24.69; 288.06 AUDPC units^2), T6 -1x NPK + Fe (24.69; 259.26 AUDPC units^2), T7 -1x NPK + Zn (23.46; 257.82 AUDPC units^2) and T9 -2 x NPK + Zn + Fe (23.46; 283.75 AUDPC units^2), denoting no significant role of Zn and Fe in stem rot development. Among the abiotic stresses, the highest mean stem rot PDI (24.69) and 273.66 AUDPC units^2 was recorded in water stagnation whereas lower PDI was recorded in drought and alkalinity (9.26; 90.04 AUDPC units^2).

Key words: *Mineral nutrition, Rice and Stem rot*

Rice (*Oryza sativa*) is an important food crop as it is the staple diet of over three billion people around the world and an important component of global food security (Hosseyni-Moghaddam and Soltani, 2013). Globally rice is grown in more than 100 countries across a wide range of climatic conditions ranging from river deltas to mountainous regions. Nearly half of Asia's population depends on rice and approximately 90% of the world's total rice production is accounting from Asian countries including China, India, Indonesia, Thailand, Philippines, Vietnam, Bangladesh and Myanmar (Muthayya *et al*., 2014).

Rice is attacked by various fungal, bacterial and viral pathogens among them diseases caused by fungi assume significance as they may result in significant crop yield losses (Kongcharoen *et al*., 2020). Diseases once considered minor are becoming major constraints in rice production. Among the different emerging biotic stresses, stem rot of rice is becoming a serious problem (Cother and Nicol, 1999). Stem rot is caused by *Magnaporthe salvinii* (Catt.) Krause and Webster (conidial state *Nakataea oryzae* (Catt.) J. Luo & N. Zhang (2013). The fungus most commonly occurs in its sclerotial state, *Sclerotium oryzae* Catt. causing substantial quantitative and qualitative losses due to increased lodging, smaller panicles, production of light chalky grains and poor milling quality particularly in waterlogged areas (Ou, 1985). About 1-5 per cent grain deterioration and 18 per cent yield loss was reported due to *S. oryzae* in almost all rice producing countries of the world

Mineral elements are applied to improve the plant health and yield. Host nutrition plays a crucial role in the outcome of the interaction between plants and pathogens. Though resistance and susceptibility are controlled genetically, a minor change in the nutritional status of the plants can have a considerable effect on severity of the disease. Mineral nutrition plays a very important role in the prevention of plant disease. Balanced plant nutrition promotes plant vigour providing tolerance to pathogen infection, improve physiological resistance to pathogen and affect the pathogen growth and multiplication. Although disease cannot be totally eliminated by any particular nutrient but the severity of the disease can be greatly reduced by manipulating the mineral nutrition of the plants (Laha *et al*., 2016a).

Mineral fertilization and fertilization levels have been reported to cause different effects on plant disease development and expression in rice. Stem rot becomes more severe when optimum to excessive amounts of N and P are supplied to rice (Williams and Smith, 2001) and proper K fertilization can significantly reduce the incidence and severity of stem rot especially in K deficient soils. In this context, the current research was carried out to evaluate the effect of mineral nutrition and abiotic stress on stem rot incidence.

MATERIAL AND METHODS

Isolation of rice stem rot pathogen

Rice leaf sheaths expressing typical symptoms of stem rot disease were collected from ICAR - Indian Institute of Rice Research (IIRR) (17° 19' 21'' N and 78° 23' 43'' E), Rajendranagar, Hyderabad, Telangana, for isolation of pathogen. The isolation was done as described by Rangaswami and Mahadevan (1999). The pathogen was identified by studying the colony characteristics on PDA (Barnett and Hunter, 1972). The pathogenicity was confirmed by following Koch's postulates. The pure culture of the isolate was prepared and stored at 4^{o}C for further use.

Analysis of available nutrients in the soil sample

The available nutrients i.e., N, P, K, Zn, Fe in the soil sample was carried out at Iota laboratories, Hyderabad.

The effect of major and minor nutrients on the disease development

Pot culture experiment was conducted at ICAR- Indian Institute of Rice Research, Hyderabad. Twenty-five days old seedlings of MTU 3626 (Prabhat) were transplanted and maintained with three hills per pot as one replication. Three replications were maintained for each treatment. *Sclerotium oryzae* was mass multiplied for 10 days on autoclaved typha stem cuttings (*Typha angustata*; an aquatic weed) soaked in a solution containing 2 per cent sucrose and 1 per cent peptone at 28 ± 2^{o}C. Plant inoculation was carried out at maximum tillering stage (45 DAS) by placing 4-5 typha stem cuttings colonized with the pathogen inside each hill (Bhaktavatsalam *et al*., 1978). The data on the disease incidence was collected at a regular interval of seven days starting from first appearance of symptoms to 66 DAS. Stem rot incidence data (stems with lesions and sclerotia) was converted to scores based on 0-9 scale (IRRI, 2013). Further, the scored data was converted into per cent disease index (PDI).

$$\text{PDI} = \frac{\text{Sum of the scores}}{\text{Numbers of observstion} \times \text{Highest number in rating scale}} \times 100$$

The effect of abiotic stress conditions on the stem rot disease development

The effect of abiotic stress conditions *viz*., drought, alkalinity and water stagnation on the disease development were studied under pot culture on susceptible variety MTU 3626. Seedlings (25DAS) were transplanted and maintained three hills per pot of size 30 × 25 cm in diameter filled with potting mixture in five replications. Soil moisture was maintained at field capacity. Plant inoculations with *S. oryzae* was carried at maximum tillering stage by placing 4-5 typha stem cuttings colonized with the pathogen inside each hill (Bhaktavatsalam *et al*., 1978). To study the effect of drought, at maximum tillering stage treatment was imposed by withholding water for 15days and observed for the disease development (Saakre *et al*., 2017). Treatment involving water stagnation was imposed during maximum tillering stage by maintaining a water depth of 25cm. Soil with pH 9 was used for alkalinity treatment.

Levels of virulence of *S. oryzae* on MTU3626

Quantitative assessment of symptoms was carried out at an interval of 7 days. Observations were recorded by using 0-9 scale (IRRI, 2013) and rate of infection was calculated (Vanderplank, 1963). The "Area Under Disease Progress Curve" was calculated by using the formula suggested by Wilcoxson *et al*. (1975).

RESULTS AND DISCUSSION

Effect of major, minor nutrients on stem rot development

The soil used in the present study was medium in soil fertility, having low nitrogen (184.5 kg ha^{-1}), medium in phosphorus (36.50 kg ha^{-1}) and potassium (277.50 kg ha^{-1}). The soil sample was deficient in zinc (0.615 mg kg^{-1}) and iron (5.250 mg kg^{-1}). The recommended dosage of fertilization followed in the present study was 119.6 kg ha^{-1} N, 52.5 kg ha^{-1} P, 40.5 kg ha^{-1} K, 25 kg ha^{-1} Zn and 20g L^{-1} Fe, as per the soil analysis report fertilizer schedule.

The treatments comprised of recommended and double the recommended dosages of NPK in combination with major and minor nutrients. The results revealed that at 66 DAS the highest stem rot severity of 39.51 per cent disease index was recorded in the treatment (T5) which received recommended dose of N, P, Zn and Fe, but, no potassium fertilization. The treatment recorded 429.22 AUDPC $units^2$ with the lowest per cent disease reduction (5.88%) over control and was found statistically at par with T4 (33.33; 419.14 AUDPC $units^2$) which received N, K, Zn, Fe but no phosphorus fertilization and control (41.98; 483.97 $units^2$). There was no significant difference between T2 -2 x RDF NPK (24.69; 288.06 AUDPC $units^2$), T6 -1 x NPK + Fe (24.69; 259.26 AUDPC $units^2$), T7 -1 x NPK + Zn (23.46; 257.82 AUDPC $units^2$) and T9 -2x NPK + Zn + Fe (23.46; 283.75 AUDPC $units^2$) indicating no significant role of Zn and Fe nutrition in stem rot disease development. The mean per cent disease index at 52DAS was the highest in treatment receiving no potassium application- T5 (14.40%) denoting the role of potassium in disease incidence. The lowest stem rot severity was recorded in treatment T8 receiving 1 x NPK along with Zn and Fe (18.52; 237.66 AUDPC $units^2$) with the highest per cent disease reduction (55.88%) over control, which indicated that there was minor role of mineral nutrients in disease development. Hence there is a need for balanced fertilization. The highest rate of infection (0.11 units day^{-1}) was recorded in T6 (RDF -Zn) and T7 (RDF -Fe) followed by T3 (RDF -N) and T5 (RDF -K) which recorded 0.10 units day^{-1}. the lowest rate of infection was recorded in treatments T2 (2x RDF NPK), T8 (1x RDF NPK + Zn + Fe) and T9 receiving 2x RDF NPK + Zn + Fe (0.07 units day^{-1}) (Table 1, Figure 1).

Effect of abiotic stresses on stem rot development

The results revealed that at 66 DAS the highest mean stem rot per cent disease index of 24.69 was recorded under water stagnation conditions (T3) with a maximum of 273.66 AUDPC $units^2$ and was on par with control (T4) (21.60, 190.84 AUDPC $units^2$). Drought (T1) and alkalinity conditions (T2) resulted in 9.26 PDI and 90.04 AUDPC $units^2$. The mean stem rot per cent disease index at the initial disease development (52DAS) was the highest in T3 (10.29%) which was significantly superior to other treatments. The rate of stem rot infection was the higher in treatment T1 and T2 (0.11 units day^{-1}) under artificial inoculation conditions. The lowest rate of infection was recorded in T3 (0.07 units day^{-1}) (Table 2, Figure 2).

The results indicate the highest per cent disease index in treatments which did not received balanced Nitrogen, Phosporus along with Zn and Fe, but without potassium fertilization, which was in agreement with previous reports (Martinez, 2021). The mean per cent disease index was high in treatments which received double the recommended dosages of NPK fertilizers when compared with treatments with recommended dosages of NPK fertilization. This trend of increased stem rot incidence with increasing N and P fertilization was in line with previous records (Datnoff *et al*., 2007). The present results regarding no effect of micronutrients (Zn and Fe) on disease development are in agreement with Clarkson *et al*. (1974) in cabbage, the addition of Fe overcame the fungus-induced Fe deficiency in the host but it did not affect the extent of infection. In the same way Kloepper *et al.* (1980a) reported that addition of iron to disease-suppressive soils counteracted the suppression and enhanced up take-in barley, whereas in a conducive soil with a high disease score Fe had no effect. Reis *et al*. (1982) also reported Fe in nutrient solution not suppressed up take-in wheat.

The present study showed that subjecting plants to abiotic stress conditions increased stem rot severity, which was in agreement with the previous reports (Dossa *et al*., 2016). The probable reasons for enhanced stem rot severity during abiotic stress may be attributed to suppression of plant resistance during abiotic stress through reduced activation of WRKY45, the central transcription factor in salicylic-acid (SA)-signalling-dependent pathogen defence in rice. This was probably through abscisic acid (ABA) signalling (Ueno *et al*., 2015). Likewise, water stagnation conditions might favour the attachment of sclerotia to the stems and disease development.

Table 1. Effect of mineral nutrition on the incidence of stem rot of rice

Treatments	Per cent disease index (PDI)*			Per cent disease reduction over control	Rate of infection (Units day-1)	AUDPC (Units^2)
	52DAS	59DAS	66DAS			
T1. NPK (1 x RDF)	8.23 (16.67)^{cd}	16.46 (23.94)^{c}	20.99 (27.27)^{c}	50	0.08	246.3
T2. NPK (2 x RDF)	10.29 (18.71)^{bcd}	18.52 (25.49)^{bc}	24.69 (29.80)^{bc}	41.19	0.07	288.06
T3. P+K+Zn+Fe (-N)	6.17 (14.39)^{d}	16.46 (23.94)^{c}	20.99 (27.27)^{c}	50	0.1	231.9
T4. N+K+Zn+Fe (-P)	12.35 (20.57)^{bc}	30.86 (33.75)^{a}	33.33 (35.26)^{ab}	20.61	0.09	419.14
T5. N+P+Zn+Fe (-K)	14.40 (22.30)^{ab}	27.16 (31.41)^{ab}	39.51 (38.94)^{a}	5.88	0.1	429.22
T6. N+P+K+ Fe (-Zn)	6.17 (14.39)^{d}	18.52 (25.49)^{bc}	24.69 (29.80)^{bc}	41.19	0.11	259.26
T7. N+P+K+Zn (-Fe)	6.17 (14.39)^{d}	18.93 (25.79)^{bc}	23.46 (28.97)^{bc}	44.12	0.11	257.82
T8. N+P+K+Zn+Fe (Recommended dosage of fertilizers (RDF))	8.23 (16.67)^{cd}	16.46 (23.94)^{c}	18.52 (25.49)^{c}	55.88	0.07	237.66
T9. N+P+K+Zn+Fe (Double the recommended dosage of fertilizers (RDF))	10.29 (18.71)^{bcd}	18.52 (25.49)^{bc}	23.46 (28.97)^{bc}	44.12	0.07	283.75
T10: Control	18.52 (25.49)^{a}	29.63 (32.98)^{a}	41.98(40.38)^{a}		0.08	483.97
C.D. (0.05)	4.15	6.58	6.79			
C.V.	13.42	14.25	12.82			

DAS- Days after sowing

* Mean of three replications

Values in the parenthesis are arc sine transformed and means with same letters are not significantly different (p= 0.05)

***S. oryzae* inoculated plants**

Figure 1. Pot study on effect of mineral nutrition on development of stem rot of rice

Figure 2. Effect of abiotic stress on stem rot incidence

T1= Drought, T2= Alkalinity, T3= Water stagnation, T4= Inoculated control

Table 2. Effect of abiotic stress conditions on development of stem rot of rice

Treatments	Per cent disease index (PDI)*			Rate of infection (Units day-1)	AUDPC (Units^2)
	52DAS	59DAS	66DAS		
T1: Drought	2.06 (8.25)^c	6.17 (14.39)^b	9.26 (17.72)^b	0.11	90.04
T2: Alkalinity	2.06 (8.25)^c	6.17 (14.39)^b	9.26 (17.72)^b	0.11	90.04
T3: Water stagnation	10.29 (18.71)^a	16.46 (23.94)^a	24.69 (29.80)^a	0.07	273.66
T4: Control	6.17 (14.39)^b	10.29 (18.71)^b	21.60 (27.70)^a	0.1	190.84
C.D. (0.05)	3.36	4.29	4.87		
C.V.	14.46	12.86	11.13		

DAS- Days after sowing
* Mean of five replications
Values in the parenthesis are arc sine transformed and means with same letters are not significantly different ($p= 0.05$)

Phosphorus and potassium have a role in incidence of stem rot disease of rice, whereas Fe and Zn have no significant role in rice stem rot incidence. So there is need of balanced fertilizer application.

In the present study, mineral fertilization without phosphorus and potassium resulted in more stem rot severity. Whereas, application of recommended dose of NPK without Fe and Zinc did not have significant effect on development of stem rot. It was observed that increase in dosage of fertilization (2X RDF) resulted in more stem rot incidence. Among the a biotic stresses studies on stem rot development, water stagnation conditions resulted in significantly higher stem rot severity in comparison to drought and alkalinity conditions.

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