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Effect of selenium on growth and yield of rice (*Oryza sativa* L.) under induced drought stress condition

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Abstract
Drought stress causes severe reduction in growth and yield of crops, especially in rice. Selenium (Se) aids in drought mitigation and improves the yield levels of crops. A field investigation was made to know the effects of foliar spraying of Se on growth, tiller production and yields of rice under drought stress during summer season of 2021 at Tamil Nadu Agricultural University, Coimbatore. Experiment was laid out in split plot design with three replications. Main plot consisted of two drought stress levels *viz*., drought stress for 20 days at panicle initiation (PI) stage (D_2) and drought stress for 25 days at PI stage (D_3), compared with D_1 (irrigation as in System of Rice Intensification method). Sub plot comprised of two Se foliar spray levels such as 10 ppm (S_2) and 20 ppm (S_3) in comparison with control (S_1). Results revealed that there was a significant reduction of growth characters (plant height, leaf area index and drymatter production), tiller production m^{-2} and grain and straw yields besides inducing earliness of phenophases (50% flowering and physiological maturity) due to drought stress. Whereas, Se foliar spraying improved the growth characters, tillers production, yields (grain and straw) in addition, delayed phenophases under drought stress condition and control. Hence, the field investigation confirmed the reduction of growth and yield due to drought stress and mitigating effect and yield improvement due to foliar spraying of Se in rice.

Keywords: rice, drought stress, selenium, growth characters, tiller production and yield

1. Introduction
Rice is a staple food for over half of the world's population, and it is cultivated in 112 countries, Asia alone accounting for 90% of global production (Parfitt *et al*., 2017) [16]. Rice crop is affected by various biotic and abiotic stresses and reduce the grain yield drastically. Drought stress is one of the most important stresses which reduced yield of rice to the tune of 53-92% (Lafitte *et al*., 2007) [12]. Due to drought stress, there was a reduction of 21% grain production during the vegetative stage, 50% during the flowering stage and 21% during the grain Filling stage in comparison with the control (Sarvestani *et al*., 2008) [21]. Rice growth and development, physiological characters, yield attributes and yield were negatively affected due to moisture stress of 20 to 25 days moisture stress in panicle initiation stage (Patnaik, 2020) [17] and reduced nutrient uptake in grain and straw (Patnaik *et al*., 2020) [18].

Despite the fact that selenium isn't necessary for plant development, research shown that it increased crop tolerance to drought (Andrade *et al*., 2018) [4]. Selenium supplementation is beneficial for seedling development of wheat under drought circumstances (Yao *et al*., 2012) [32]. Irrespective of varieties, foliar spraying of Se increased grain yield of rice (Luo *et al*., 2019; Yong *et al*., 2008) [13, 33]. Drought stress has been reduced due to foliar Se treatment, which had increased growth and production (Ali *et al*., 2020) [3]. Se treatment primarily enhanced the accumulation of antioxidant enzymes and proline, which increased plant growth and yield under drought stress (Shen *et al*., 2008) [23].

Since it is evident from the above that drought stress is detrimental in rice and Se has a role in reducing adverse effects of drought stress in many crops. But, impact of selenium on mitigation effect on rice is meagre and this study aimed to know the impacts of Se application under induced drought stress condition in the most critical stage (panicle initiation) of rice.

2. Materials and Methods
Field research was done during summer season (February – June) of 2021 at Wetland farms, Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore. The farm is situated at 11°N latitude and 77°E longitude, at an altitude of 426.7 metres above mean sea level, in Tamil Nadu's western agro-climatic zone. The soil of experimental site is *Typic*

Haplustalf, which is part of the Noyyal series. The soil is clay loam in texture with the pH and EC of 8.1 and 0.44 dS m^{-1}, respectively. Organic carbon content of the soil was 0.55 g kg^{-1} of soil. Soil was low in available nitrogen (224.2 kg ha^{-1}), high in available phosphorous (33.4 kg ha^{-1}) and available potassium (618.3 kg ha^{-1}).

During the cropping season, 71.5 mm of rainfall received in 12 rainy days. The average maximum temperature was 34.2 °C, while the average lowest temperature was 23.8 °C. The average relative humidity at 0722 hrs and 1422 hrs recorded was 81.7 and 46.1 per cent, respectively. The mean solar radiation recorded during crop growth period was 359.5 Cal. cm^{-2} day^{-1} with an average of 8.1 bright sunshine hours. The mean evaporation recorded during the crop period was 6.9 mm.

Experiment was laid out in split plot design with three Drought stress treatments in main plot and three Se spraying treatments in the sub plot with the plot size of 5.0 m x 4.0 m. Treatments were replicated three times. Main plot treatments were D_1 - Irrigation as in System of Rice Intensification (SRI) method; D_2 - Drought stress for 20 days from panicle initiation stage; D_3 - Drought stress for 25 days from panicle initiation stage and sub plot treatments were S_1 - Water spray; S_2 – Selenium foliar spray @ 10 ppm; S_3 - Selenium foliar spray @ 20 ppm. Foliar spray was given twice for each treatment after completion of drought stress period as per treatment. For the treatments D_2 and D_3, drought stress was induced at the panicle initiation stage by withholding water and not irrigating for 20 and 25 days, respectively. Irrigation was given after the stress period. The field seepage was stopped by creating a buffer channel and one-foot-long polythene sheet covering around each plot. The D_1 treatment was irrigated following the SRI method. For foliar spraying, sodium selenate (Na_2SeO_4) was used as a source of Se. Weighed 1.0 g of sodium selenate and diluted in 1000 ml of water in a 1.0 litre volumetric flask to obtain 1000 ppm Se stock solution. From stock solution, 10 ppm and 20 ppm were prepared and used for spraying.

The following observations were taken during the study. Plant height was measured from base to the tip of the panicle. In each treatment, five tagged plants were chosen and measured using a metre scale and represented in centimetres (cm). Leaf area index (LAI) was calculated using following formula (Palaniswamy and Gomez, 1974) [15].

$$LAI = \frac{L \times B \times K \times \text{Total number of green leaves per hill}}{\text{Spacing (cm}^2\text{)}}$$

Where,
L - Length of the third leaf from top (cm),
B - Breadth of the third leaf from top (cm), and
K - Constant (0.75).

Drymatter production was weighed from five plants in each treatment and plants were oven dried 80±5 °C and mean values were expressed in kg ha^{-1}. The numbers of tillers in each hill of five chosen plants were noted and mean value is expressed in tillers m^{-2}. In every plot, flowering count was obtained by visual observation from the beginning of flowering. By dividing the number of flowered tillers by the total number of tillers, the days to 50% flowering was calculated. When the grain becomes a golden yellow colour and lower leaves begin to senesce, the date is recorded in order to determine the number of days to physiological maturity. The net plot was harvested, threshed, washed, dried, and weighed at 14 per cent moisture. Grain yield was calculated from the grains collected in the net plot (kg ha^{-1}). The weight of paddy straw gathered from each net plot area was sun dried and straw yield was calculated and expressed in kg ha^{-1}.

The data were analysed using analysis of variance (ANOVA) as suggested by Gomez and Gomez (2010) [9].

3. Results and Discussion

3.1. Growth characters

Effect of drought stress on plant height of rice was influenced significantly (Table 1). Irrigation as in SRI method produced significantly taller plants (81.9 cm) compared to 20 days and 25 days drought stressed rice. Extreme moisture stress (i.e., a period of 20 to 25 days) might have prevented cell division or cell expansion, and the photosynthetic process and subsequent translocation. The length and extension of the cell were reduced, resulting in a shorter plant height under drought was reported (Nonami, 1998) [14]. This results fall in findings of Singh *et al*. (2018) [24].

Table 1: Effect of drought stress and foliar spray of selenium on growth characters and tiller production of rice

Treatments	Plant height (cm)	Leaf area index (LAI)	Drymatter production (kg ha^{-1})	Number of tillers m^{-2}
D_1	99.4	2.25	7054	544.4
D_2	91.4	2.23	4912	458.3
D_3	90.6	1.75	4850	390.0
SEd.	1.0	0.07	186	20.9
CD (5%)	2.8	0.21	517	57.9
S_1	91.0	1.86	5337	430.9
S_2	94.5	2.08	5636	476.4
S_3	95.9	2.29	5843	485.3
SEd.	0.8	0.10	171	20.7
CD (5%)	1.7	0.21	373	45.1

M_1 - Irrigation as in System of Rice Intensification (SRI) method; M_2 - Drought stress for 20 days from panicle initiation stage; M_3 - Drought stress for 25 days from panicle initiation stage; S_1 - Water spray; S_2 – Selenium foliar spray @ 10 ppm; S_3 - Selenium foliar spray @ 20 ppm

Similar to plant height, leaf area index and drymatter production were also reduced due to drought stress of 20 and 25 days (Table 1). Drought stress altered plant physiological characteristics, affecting plant morphology and negatively impacting developmental and growth (Wang *et al*., 2015; Tadina *et al*., 2007) [28, 25]. Patnaik (2020) [17] reported that moisture stress had reduced leaf area index and drymatter production under prolonged induced drought stress in rice.

Smaller leaf area production is the only option to reduce water loss during drought conditions and due to drought stress. Reduced plant height, leaf area index and tiller production as evidenced in the present study ultimately resulted in decrease of drymatter production.

Due to application of selenium (10 ppm and 20 ppm), rice plants produced significantly taller plants, higher LAI and drymatter production under both normal and drought condition than control (Table 1). Applying selenium at low concentrations had positive benefits and improved plants ability to withstand drought stress (Germ *et al*., 2005) [8]. Under drought circumstances, foliar sprays of Se greatly enhanced the morphological characteristics of rice plants. Our findings indicated that 20 ppm of selenium is more effective in promoting rice growth and development in both normal and drought conditions. Similar results were found in plant height (Aissa *et al*., 2016; Ikram *et al*., 2020, Andrade *et al*., 2018) [2, 11, 4], leaf area index (Teimouri *et al*., 2014) [26] and drymatter production (Thuc *et al*., 2021) [27]. Interaction between drought stress and selenium spray on plant height, leaf area index, drymatter production of rice was not significant.

3.2. Tiller production

Data on number of tillers per m^{-2} of rice due to drought stress and foliar spraying of selenium was given in Table 1.

Due to induced drought stress, there was a significant variation on number of tillers of rice. At maturity, there was a drastic reduction of number of tillers in rice (458.3 m^{-2} and 390.0 m^{-2}) due to D_2 and D_3, respectively over control (544.4 m^{-2}). Reduced tiller development under drought stress might be due to the plant's inability to generate adequate assimilates under water stress, which hindered photosynthesis. Another cause for decreased tiller production might be insufficient water absorption, which fall short for food preparation and hence, inhibited meristem tissue cell division (Zubaer *et al*., 2007) [34]. Salsinha *et al*. (2020) [20] and Singh *et al*. (2018) [24] also confirmed reduced tiller production due to drought stress in rice.

Selenium spraying had significant influence on number of tillers of rice at maturity stage. Selenium spray with either 10 ppm (476.4 m^{-2}) or 20 ppm (483.3 m^{-2}) produced significantly more tillers than control (430.1 m^{-2}). The positive impact of Se on chloroplast and photosynthesis under water deficiency condition that is responsible for vegetative development like number of branches (Habibi, 2013; Balal *et al*., 2016; Dong *et al*., 2013) [10, 5, 7]. This finding was validated by Ahmad *et al*. (2019) [1] in canola. Interaction between drought stress and foliar spraying has registered non significant results.

3.3. Phenophases development

Drought stress had significant influence on phenophases development and earliness was noticed in days to 50% flowering and days to physiological maturity due to induced drought stress in rice (Table 2). It might be due to scarcity of water during vegetative stage which maight have reduced the vegetative growth and induced the plants into reproductive phase. On contrary, Patnaik (2020) [17] reported delayed flowering and physiological maturity in rice crop due to moisture stress at panicle initiation stage.

Foliar spraying of selenium delayed days to 50% flowering and physiological maturity significantly than control. Selenium spray might be increasing vegetative growth for assimilate accumulation in sink leading to delayed flowering and maturity. On contrary, Shekari *et al*. (2019) [22] found accelerated flowering.

Table 2: Effect of drought stress and foliar spray of selenium on phenophases and yield (kg ha^{-1}) of rice

Treatments	Days to 50% flowering	Days to physiological maturity	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
Main plot: Drought stress				
D_1	89.8	108.6	6910	9659
D_2	83.8	104.1	6092	7159
D_3	82.8	104.6	6051	7139
SEd.	0.6	0.92	99	270
CD (5%)	1.7	2.56	276	750
Sub plot: Selenium spray				
S_1	84.5	104.6	6032	7525
S_2	85.7	106.0	6323	8145
S_3	86.0	106.7	6698	8287
SEd.	0.5	0.74	60	144
CD (5%)	1.1	1.61	132	314

M_1 - Irrigation as in System of Rice Intensification (SRI) method; M_2 - Drought stress for 20 days from panicle initiation stage; M_3 - Drought stress for 25 days from panicle initiation stage; S_1 - Water spray; S_2 – Selenium foliar spray @ 10 ppm; S_3 - Selenium foliar spray @ 20 ppm

3.4. Grain and straw yield

Grain yield of rice was significantly influenced by drought stress, foliar spraying of selenium (Table 2). There was a reduction of 11.83% yield due to drought stress of 20 days and 12.43% due to induced drought stress of 25 days at panicle initiation stage compared to following SRI method (6910 kg ha^{-1}). Reduced plant height, lower LAI, lesser drymatter production, and lower number of tillers may have contributed to a drop in yield attributes and in turn grain yield. Decrease in growth might reduce photosynthesis process negatively which will ultimately results in assimilate production. Due to high soil moisture deficit stress, the yield was reduced by 54.9% (Qun *et al*., 2017) [19]. Mild stress resulted in a yield loss of 5-38%, whereas, severe stress resulted a loss of 26-67% (Yang *et al*., 2003) [31].

Foliar spraying of selenium (10 ppm) twice after drought stress increased 4.82% grain yield whereas foliar spraying of 20 ppm had 11.04% increase over control (6030 kg ha^{-1}). The results of straw yield of rice were similar as that of grain yield. Grain and straw yield is an index of all the growth characters (plant height, LAI, drymatter production and number of tillers). The present findings revealed that foliar spraying of selenium increased all of growth characters which may resulted in production of higher yield. Application of selenium promoted the growth and yield of rice seedlings (Wang *et al*., 2013) [29], lettuce seedlings (Xue *et al*., 2001) [30], and soybean seedlings (Djanaguiraman, *et al*., 2004) [6].

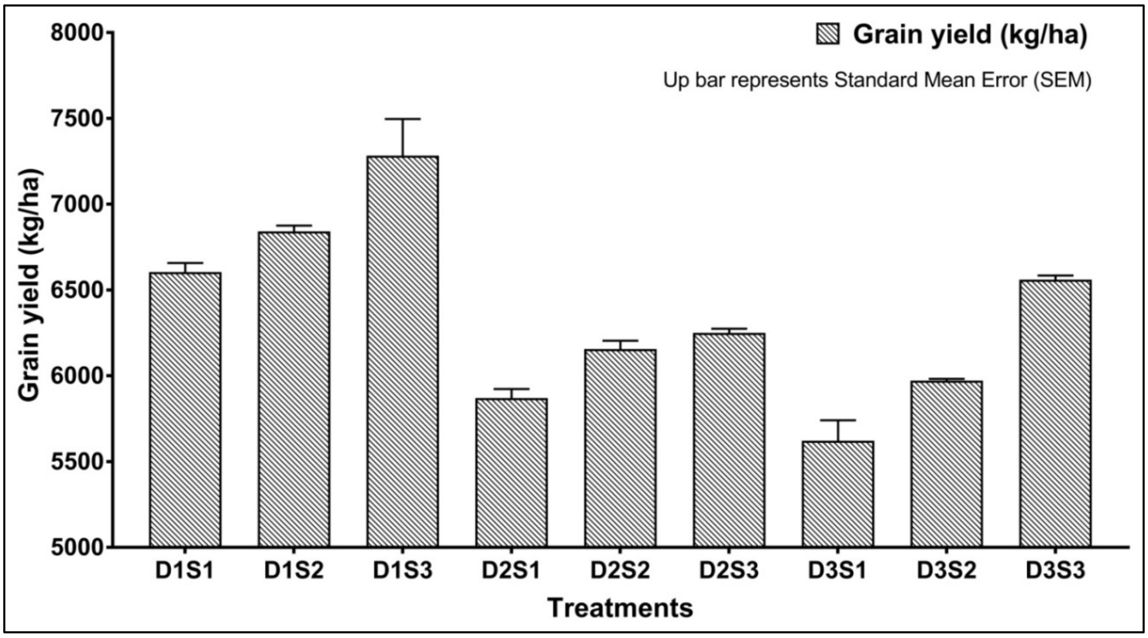

Fig 1: Effect of drought stress and foliar spray of selenium on grain yield (kg/ha) of rice

Interaction between drought stress and selenium foliar spraying was significant on grain yield of rice (Fig. 1). Irrigation by following as in SRI method in combination of foliar spraying of selenium (20 ppm) registered significantly higher grain yield (7283 kg ha^{-1}) compared to all other combinations. In present study, it is evident that all growth characters were more due to combination of selenium foliar spray and irrigation following SRI method, might have resulted in production of higher grain yield. The least grain yield (5631 kg ha^{-1}) was noted when rice plants were stressed for moisture for 25 days at panicle initiation stage without foliar spray. This was due to negative impact of drought stress on growth of rice and resulted drastic reduction in yield.

4. Conclusion

The field experimental results revealed that induced drought stress at panicle initiation stage had drastically reduced the growth characters, tiller production, and grain and straw yields. Under both normal and drought induced conditions, foliar application of Se (either 10 ppm or 20 ppm) resulted in a significant increase in growth parameters (plant height, LAI, drymatter production) and tiller development, which subsequently enhanced rice grain and straw yields. Hence, the field study confirmed that selenium foliar spraying to be an efficient strategy for improving rice yield under drought conditions.

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