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Effect of Silixol on Growth and Yield Attributes of Rice in Drought Condition

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ABSTRACT: A field experiment was carried out in the kharif seasons of 2022, to study the screening attributes for determining the optimal concentration of Silixol (0.6%) and selecting high-performing rice genotypes to assess the impact of drought on morpho-physiological characteristics and yield attributes of rice genotypes. Eight rice genotypes were subjected to several treatments including control, drought during blooming, foliar application of Silixol with irrigation and foliar application of Siliconl (Silixol 0.6%) during drought. Application of Silixol in all genotypes exhibited the best total dry matter production and leaf area index, relative water content and yield attributes compared to other treatment in the study, both in drought conditions and with foliar Siliconl spray during drought. KRH-1 had the highest number of productive tillers under drought conditions and foliar Siliconl spray. US-312 achieved the highest grain output in drought conditions. These genotypes are recommended for drought-prone regions, and their yield potential can be enhanced by applying Siliconl foliar spray during the flowering stage under drought conditions. After analysing the recorded parameters, it has been concluded that further biochemical assessment of rice under application of Silixol is needed for ultimate concentration and genotype selection.

Keywords: Silicon, Silixol, Rice, Yield attributes, Drought.

INTRODUCTION

Rice (*Oryza sativa* L.) ranks as the second most important cereal crop cultivated for commercial purposes globally. Rice is the primary source of nutrition and sustenance for over fifty percent of the global population. As a result, in order to attain food security and meet the demands of an expanding population, a greater quantity of rice is required. Flood irrigation systems are responsible for more than 75% of the worldwide rice production. Rice, in comparison to other agricultural produce, exhibits a comparatively higher susceptibility to water scarcity, particularly during critical growth phases (Panda *et al*., 2021). Drought stress significantly impacts on rice physiological traits and yield during the flowering stage (Panda *et al.,* 2021). Drought is, on a global scale, one of the most catastrophic climatic phenomena that endanger agricultural production. Water scarcity hinders the process of cell division, leading to the development of short stems, diminished internodal length, shortened tillering capability and a compromised root system (Hannan *et al*., 2020). Additionally, it reduces both dried and fresh biomass (Sikuku *et al*., 2012). Rice plants subjected to drought stress exhibit variable root lengths, modified root morphology, and diminished root development, according to a study (Kim *et al.,* 2020). Furthermore, drought stress conditions have been found to have detrimental effects on numerous metabolic processes, such as respiration, photosynthesis, ion absorption, hormone production, and nutrient assimilation (Farooq *et al.,* 2008; Usman *et al*., 2013; Lee *et al.,* 2015). Significant harm can also be inflicted by drought stress on enzyme systems, photosynthetic pigments, gas exchange systems, electron transport systems, and carbon reduction pathways (Ashraf and Harris 2013). Water scarcity in rice plants commonly manifests in the leaves, where as it leads to the degradation of chlorophylls (Chl) a and b, as well as carotenoids, which are vital for the process of photosynthesis (Farooq *et al*., 2009). Drought stress is a prevalent abiotic stress that significantly hampers agricultural productivity. Therefore, cereal crops, such as rice, exhibit divergent adaptive mechanisms in order to manage arid conditions (Javaid *et al.,* 2022). Plants exhibit a multitude of molecular, morphological, physiological, and biochemical characteristics in order to alleviate the detrimental impacts of arid stress (Choudhary *et al.,* 2009). Such morphological mechanisms of drought avoidance and phenotypic flexibility can aid crop plants in surviving drought duress. Choudhary *et al.* (2009) state that the root system's architecture permits a greater quantity of water to be stored for drought tolerance. Water preservation within cells and tissues, maintenance of cell membrane stability, and the secretion of growth regulators endogenously are a few of the physiological mechanisms that are linked to the response of plants to drought stress conditions. Molecular modifications occur in plant genes to prevent the deleterious consequences of insufficient water availability. Therefore, genetic factors regulate these adaptive responses throughout various phases of plant development (Choudhary *et al.,* 2009). As a screening instrument for drought tolerance in plants, relative water content (RWC) is a significant indicator of water status (Liang *et al.,* 2007; Choudhary *et al*., 2009). The leaf rolling factor in rice is regarded as a highly reliable criterion for assessing drought tolerance on a large scale during large-scale screenings (Pandey and Shukla 2015). The application of silica to increase plant resistance to environmental stresses is widespread. While not categorised as a vital element for plants, it has been shown to mitigate various types of biotic and abiotic stresses (Liang *et al.,* 2007; Hamayun *et al*., 2010). Application of silica to plants has been shown in numerous studies to regulate RWC, net photosynthetic ratio, intercellular CO_2 level, stomatal conductance, and transpiration ratio in addition to activating the plant defence system (Romero-Aranda *et al.,* 2006; Gong *et al.,* 2008; Chen *et al.,* 2016; Hussain *et al*., 2021). Furthermore, silica is of utmost importance in enhancing cellular metabolic rates and physiological activities of plants during periods of drought stress; consequently, this contributes to improved water use efficiency, growth, and biomass (Gong *et al.,* 2003; Ahmad *et al*., 2007; Li *et al.,* 2018).

Hence, the objective of the present investigation was to assess the drought tolerance of hybrid rice cultivars of Indiaunder drought stress ecology which was also evaluated by the spray with Silixol (0.6%) as treated one. for analysing the various morphological and yield attributing traits.

MATERIALS AND METHODS

This experiment was conducted during *Kharif* season 2022, at the experimental area of College of Agriculture, Rewa, Madhya Pradesh. Most popular and promising Eight hybrid rice cultivars differing in drought tolerance *viz.,* 27P63, HRI-174, IIRRH-143, JKRH-3333, US-312, US-314, KRH-4, Sahbhagidhan were used as plant materials for this study. The experiment was laid out in Randomised Block Design (RBD) with three replicates and four treatments namely control (T1), application of Si @ 0.6% at tillering, panicle initiation, 50% flowering and milky grain stages (T2), application of Si (as in T2) in combination with droughtstress; by withholding irrigation 12 days before flowering and 10 days after anthesis stage (T3) and drought stress by withholding irrigation (T4).The soils are normal with pH value 7.3 and electrical conductivity varied from 0.37-0.44 dsm^{-1} at 25°C . The soils are low in available nitrogen, medium in available P_2O_5 and high in available potassium.

Measurements:

Plant height: Plant height was measured from ground level to the tip of the topmost leaf at harvesting stages from ten randomly selected plants, and the average was calculated and expressed in centimetres.

Relative water content: The Leaf relative water content (RWC %) was determined by measuring the fresh weight and turgid weight of 0.5 g fresh leaf samples after soaking them in water for 4 hours, and then drying them in a hot air oven until a consistent weight was reached (Weatherley, 1950)

RWC (%) = (Fresh weight - Dry weight)/ (Turgid weight- Dry weight) × 100

Number of tillers hill^{-1}

Leaf area index Leaf area index(LAI) of rice at flowering was worked out without removing the leaves by using the following formula as proposed by Palaniswamy and Gomez (1974).

$$\text{LAI} = \frac{\text{L} \times \text{W} \times \text{K} \times \text{Number of leaves hill}^{-1}}{\text{Spacing (cm}^2\text{)}}$$

Where, L=Maximum length of 3rd leaf blade from the top (cm)

W=maximum width of the same leaf (cm)

K = Adjustment factor (0.75)

Drymatter: Production Ten plants per plot from the destructive row, at harvest, were removed in all the experiments. These samples were first air- dried and then oven dried at 70°C till a constant weight obtained and the weight was recorded. The mean dry weight was expressed in (g/m^2).

Yield attributes: The grain yield was measured in gram per square metre (g/m^2) from the net plot area and reported at a 14 percent moisture level. Additional yield characteristics such as panicle number (m^{-2}), Test weight (g) were also documented.

RESULT AND DISCUSSION

The study aimed to assess the tolerance levels of eight rice genotypes by evaluating their growth performance, leaf area index, relative water content (RWC), dry matter production, and yield under drought stress conditions. Additionally, the study examined the Silixol under drought stress.

Plant Height: All eight rice genotypes experienced reduced plant height due to drought stress compared to the irrigated plants. The trial demonstrated that dryness led to a 9.8% reduction compared to the control group as seen in Table 1. All eight genotypes showed an increase in plant height under both circumstances when treated with 0.6% Silixol. In drought conditions, the greatest increase in plant height (10.6%) was seen when Silixol was applied to KRH-4. The tallest plant height was recorded in US-312 across all treatments. The findings are consistent with Singh *et al.* (2005) research, indicating that different Siliconl levels significantly improved plant height, dry matter production, panicles per m^2, full grains per panicle, test weight, and rice yield. Jawahar and Vaiyapuri (2010) discovered similar outcomes with the use of Silixol, which can boost rice plant height in both well-watered and dry conditions, confirming the present results. Drought was found to restrict cell proliferation, leading to decreased leaf growth. The underside of the leaf leads to reduced water uptake from the soil and decreased transpiration.

Leaf area Index: Leaf area index (LAI) is essential for assessing dry matter production in plants. There was significant heterogeneity in LAI levels among different genotypes and treatments. The Silixol application (T2) had the highest average leaf area index of 5.59, while the lowest average leaf area index of 3.71 was seen in the water stress treatment (T4). KRH-4 genotype had the greatest Leaf Area Index (LAI) of 5.02, followed by US-312 with a LAI of 4.92 when exposed to drought stress and treated with Silixol. In HRI-174, the lowest Leaf Area Index (LAI) of 3.17 was recorded under drought stress circumstances (T4), while, the highest LAI of 6.58 was observed in SB-Dhan in Silixol treatment (T2) closely in accordance with the findings reported by Pati *et al.* (2016). Similarly Sarma *et al.* (2017); Meena *et al.* (2014) demonstrated significant differences in leaf area index caused by Silicon treatment. Using Silicon solute can enhance the strength of plant sources and sinks, boost disease resistance and result in healthier, more developed leaves with increased leaf area. The rise in Leaf Area Index (LAI) is attributed to the significant increase in leaf dimensions (length and width), heightened rates of cell division and enlargement, quicker growth, and enhanced quality of vegetative growth resulting from the application of Silicon in conjunction with the prescribed amount of fertiliser. This is consistent with the research conducted by Jaliya *et al.* (2008); Jat *et al.* (2010); Bisht *et al.* (2012).

Relative water content. The relative water content (RWC) of a leaf indicates its hydration level in relation to its maximum water retention capacity when completely turgid. Relative Water Content (RWC) assesses the leaf's water deficit, indicating the degree of stress induced by drought and high temperatures. RWC integrates leaf water potential (ψ) and osmotic adjustment to assess plant water status. An advantageous genotype that can maintain turgid leaves in challenging settings can provide physiological benefits by alleviating stress. Significant differences in water content were observed among treatments, as indicated in Table 2. The Silixol treatment (T2) had the highest average Relative Water Content (RWC) of 90.0%, while the water stress treatment alone (T4) had the lowest average RWC of 74.0%. The treatment of Silixol (T2) increased the Relative Water Content (RWC) by 2.27% compared to the control group (T1). Water stress (T4) reduced RWC by 15.90%, while the combination of Silixol plus water stress (T3) reduced RWC by 10.22%. The genotypes examined displayed negligible variation in Relative Water Content (RWC). HRI-174 had the lowest average relative water content (RWC) of 79.0%, whereas US-312 had the highest average RWC of 87.0%. Silica fertiliser has a beneficial impact on Relative Water Content (RWC) during drought stress situations (Othmani *et al.*, 2020; Nabizadeh *et al.*, 2010). Combining Silicon (Si) and Selenium (Se) when applied to rice plants increases Relative Water Content (RWC), with a greater effect seen when both Si and Se are used simultaneously (Ghouri *et al.,* 2021).

Total dry matter: Total dry matter production (TDMP) refers to the plant's ability to efficiently use light, water, and nutrients to produce photosynthates. The investigation revealed that drought significantly affected TDMP, leading to an average decrease of 40% compared to the control group (Table 2). The maximum production in IR64 was 51.9 gram per plant, and the minimum was 33.9 gram per plant. Chen *et al.* (2018) reported that applying Silicon may enhance TDMP under drought by improving gas exchange parameters, photochemical efficiency, mineral nutrient absorption, leaf thickness, cell silicification, and Silicon deposition in plant tissues.

Yield and yield attributes: Drought stress significantly influenced the yield and yield characteristics. Silixol treatment dramatically enhanced the grain yield under stressful conditions. Results showed a notable difference in the number of panicles m^{-2} between treatments as seen in Table 3. The highest average number of panicles (336.3) was observed with Silixol treatment (T2), whereas, the lowest average number of panicles (247.6) was observed with water stress alone (T4). Silixol application (T2) increased the number of panicles m^{-2} as compared to the control (T1). Water stress alone (T4) decreased the numbers of panicles m^{-2} by 24.76%, whereas Silixol + water stress (T4) decreased it by 15.12%. KRH-1 has the largest mean number of panicles at 319.92, while 27P63 has the lowest mean number at 283.76. The interaction between treatments and genotypes for panicle number per square metre was deemed negligible. Research at IRRI has shown that Silicon deficit consistently decreases the quantity of panicles per square metre (IRRI 1993). There was an 8.92% increase in the number of panicles per square metre when 500 kg ha^{-1} of Silicon was used, compared to the control group (Gholami and Falah 2013). Similar findings were also inconformity with the present findings reported by Pati *et al.* (2016); Coung *et al.* (2017); Ullah *et al.* (2017); Jawahar *et al.* (2015). The amount of plant material produced during the growth of the crop and the movement of this material to the panicle are the main factors influencing the rice grain yield (Yoshida, 1972). The data showed notable variations in grain yield between different treatments, as indicated in Table 3. Silixol (T2) resulted in the highest mean grain production of 773.4 g m^{-2}, which was comparable to control output of 751.7 g m^{-2}. The lowest grain yield of 557.7 g m^{-2} was recorded with water stress alone (T4). Silixol application (T2) increased grain yield by 3.60% as compared to the control (T1). Water stress alone (T4) decreased grain output by 25.76%, while Silixol + water stress (T3) decreased grain yield by 19.88%. The highest average grain yield of 708.62 g m^{-2} was seen in US-312, whereas SB. Dhan had the lowest average grain yield of 632.70 g m^{-2}. The rise in grain yield due to Silicon application is linked to the increase in tillers per hill, grains per panicle, and test weight. Nayar *et al.* (1982); Singh *et al.* (2005); Prakash *et al.* (2010) all observed a comparable rise in rice grain yield due to Silicon application. The increased grain yield from Silicon application may be due to improved leaf erectness, allowing better sunlight penetration, resulting in increased photosynthetic activity and higher carbohydrate production. Rani *et al.* (1997); Korndorfer *et al.* (2001); Rodrigues *et al.* (2003); Singh *et al.* (2006) also observed comparable outcomes. The results showed substantial differences across the treatments for test weight as presented in Table 3. The highest average test weight of 21.80 g was observed when Silixol (T2) was applied, while the lowest average value of 18.70 g was seen with water stress alone (T4). Compared to the control group (T1), test weight decreased by 10.00% under water stress alone (T4) and by 2.88% with Silixol + water stress (T3). US-312 had the greatest average test weight of 23.90 g, while 27P63 had the lowest average test weight of 16.20 g. The rise in thousand grains weight may be related to the positive impact of Silicon on enhancing photosynthetic activity and plant feeding. Singh *et al.* (2007) found a comparable rise in the thousand grains weight of paddy as a result of Silicon application. Dallagnol *et al.* (2014) reported a 12% increase in 1000-grain weight when Si was externally supplied. The increase in grain mass is presumably due to the higher deposition of Silicon on the palea and lemmas, as reported by Balastra *et al.* (1989), even though Silicon deposition on rice grain hulls was not assessed. The increased Silicon deposition is linked to high panicle transpiration during the grain filling stage, as Siliconl transit and deposition in plant tissues rely on transpiration rates in various plant organs (Yoshida *et al.,* 1962).

Thus, it may be summarised and concluded that drought stress has a substantial impact on the growth, physiological characteristics and production of rice. The application of Silixol has improved the morphological features and production of rice in both well-watered and water stress circumstances by reducing the deleterious effect of drought stress. Hence, it is stated that Silicon application may play a vital role and used as an effective tool through breeding efforts to enhance the yield quality and develop drought-resistant rice varieties.

Table 1: Influence of Silixol on rice plant height and leaf area index under drought conditions.

Genotype	Plant Height (cm)				Leaf Area Index (LAI)			
	Control (T1)	Irrigated + 0.6% Silixol (T2)	Drought + 0.6% Silixol (T3)	Drought (T4)	Control (T1)	Irrigated + 0.6% Silixol (T2)	Drought + 0.6% Silixol (T3)	Drought (T4)
27P63	111	114	101	97	4.55	5.72	4.13	3.47
HRI-174	109	114	106	99	4.76	5.61	3.66	3.17
IIRRH-143	114	121	104	95	4.50	4.72	4.33	3.87
JKRH-3333	107	124	106	100	5.10	5.60	4.26	4.05
US-312	118	118	115	103	5.44	5.87	4.92	4.15
US-314	106	115	101	99	4.11	5.12	3.83	3.53
KRH-4	110	117	102	95	4.78	5.46	5.02	4.05
SB.DHAN	121	129	121	120	6.45	6.58	4.36	3.98
Mean	**112**	**119**	**107**	**102**	**4.96**	**5.59**	**4.32**	**3.71**
	C.D.	**SE(d)**	**SE(m)**		**C.D.**	**SE(d)**	**SE(m)**	
G	3.109	1.552	1.097		0.339	0.169	0.120	
T	2.199	1.097	0.776		0.240	0.120	0.085	
G×T	6.219	3.104	2.195		0.678	0.338	0.239	

Table 2: Influence of Silixol on Relative water content and total dry matter of rice under drought conditions.

Genotype	Relative water content (%)				Total dry matter (g/m^2)			
	Control (T1)	Irrigated + 0.6% Silixol (T2)	Drought + 0.6% Silixol (T3)	Drought (T4)	Control (T1)	Irrigated + 0.6% Silixol (T2)	Drought + 0.6% Silixol (T3)	Drought (T4)
27P63	89.00	91.00	80.00	77.00	1975.00	2025.00	1794.00	1581.00
HRI-174	85.00	89.00	73.00	69.00	1634.00	1778.00	1433.00	1399.00
IIRRH-143	88.00	90.00	80.00	73.00	1780.00	1932.00	1692.00	1501.00
JKRH-3333	88.00	89.00	77.00	71.00	1819.00	2002.00	1583.00	1465.00
US-312	91.00	93.00	83.00	81.00	2046.00	2150.00	1821.00	1744.00
US-314	88.00	90.00	81.00	78.00	1917.00	1958.00	1634.00	1583.00
KRH-4	87.00	89.00	75.00	67.00	1803.00	1912.00	1656.00	1472.00
SB.DHAN	89.00	90.00	86.00	79.00	1742.00	1860.00	1593.00	1543.00
Mean	88.00	90.00	79.00	74.00	1839.00	1952.00	1651.00	1536.00
	C.D.	**SE(d)**	**SE(m)**		**C.D.**	**SE(d)**	**SE(m)**	
G	2.03	1.02	0.72		39.30	19.61	13.87	
T	1.44	0.72	0.51		27.79	13.87	9.81	
G×T	4.07	2.03	1.44		78.60	39.22	27.74	

Table 3: Influence of Silixol on panicle number, grain yield and test weight of rice under drought conditions.

Genotype	Panicle number (m^{-2})				Grain yield (g/m^2)				Test weight (g)			
	Control (T1)	Irrigated + 0.6% Silixol (T2)	Drought + 0.6% Silixol (T3)	Drought (T4)	Control (T1)	Irrigated + 0.6% Silixol (T2)	Drought + 0.6% Silixol (T3)	Drought (T4)	Control (T1)	Irrigated + 0.6% Silixol (T2)	Drought + 0.6% Silixol (T3)	Drought (T4)
27P63	320.3	326.0	250.7	238.0	751.9	761.0	648.5	575.2	16.9	17.4	15.9	14.6
HRI-174	334.7	341.0	302.3	259.0	730.2	766.3	549.8	535.6	20.1	21.7	22.6	21.8
IIRRH-143	319.7	341.0	291.3	263.0	761.5	796.5	632.7	572.7	23.6	23.9	22.3	19.6
JKRH-3333	336.0	341.0	285.0	213.3	761.1	790.7	568.2	530.7	16.8	20.0	21.3	18.4
US-312	339.3	325.7	264.0	231.3	793.3	799.2	652.2	589.8	24.0	24.9	23.9	22.8
US-314	322.3	335.7	295.0	226.3	784.8	786.7	539.0	522.0	22.8	23.6	19.3	19.5
KRH-4	325.7	357.3	295.0	301.7	747.7	791.2	634.8	581.3	18.5	18.9	17.8	16.0
SB.DHAN	335.0	322.7	250.7	248.3	680.2	702.8	590.6	554.7	23.7	23.8	18.2	17.2
Mean	329.1	336.3	279.3	247.6	751.3	774.3	601.9	557.7	20.8	21.8	20.2	18.7
	C.D.	**SE(d)**	**SE(m)**		**C.D.**	**SE(d)**	**SE(m)**		**C.D.**	**SE(d)**	**SE(m)**	
G	20.50	10.23	7.23		28.96	14.45	10.22		1.26	0.61	0.43	
T	14.49	7.23	5.11		20.48	10.22	7.23		0.86	0.43	0.30	
G×T	N/A	20.46	14.47		57.92	28.91	20.44		2.43	1.22	0.86	

CONCLUSIONS

The findings showed that drought stress has a substantial impact on the growth, physiological characteristics and production of rice. The application of Silixol has improved the morphological features and production of rice in both well-watered and water stress circumstances by reducing the deleterious effects of drought stress. Thus, including silicon into breeding efforts is essential to enhance yield quality and develop drought-resistant rice varieties.

FUTURE SCOPE

The future study direction should involve a multidisciplinary strategy that integrates biochemical and molecular investigations to enhance our understanding of the complex connections between silixol, rice genotypes, and drought stress. This thorough investigation is crucial for expanding the actual use of silixol in agriculture, ultimately supporting sustainable and resilient rice farming in adverse environmental situations.

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Conflict of Interest. None.

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