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Performance of different zinc sulfate level on survival, morphological and biochemical parameters of Sub1 and Non-Sub1 rice varieties under submerged condition

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Abstract
An experiment was performed to evaluate the impact of zinc sulfate by examining survival rate, growth attributes, and biochemical parameters under the submerged and non-submerged conditions to enhance submergence tolerance in Sub1 and non-Sub1 rice varieties. A fully randomized block design was followed with three treatments, three replications, and five chosen rice varieties centered on submergence resistance and susceptibility. Sowing seed s directly with the treatments comprises *viz*. T1: 0.0 mg ZnSO4 per kg of soil, T2: 5.0 mg ZnSO4 per kg, T3: 10 mg ZnSO4 per kg of soil. Treatments were performed in both submerged and non-submerged (controlled) pots at sowing. After 30 days of sowing, fifteen days of full sub mergence. It follows that zinc sulfate @10 mg/kg soil greatly improved survival percentage, growth qualities, and biochemical parameters of Sub1 and nonSub1 rice varieties even after 15 days of total submergence.

Keywords: Submergence, zinc sulfate, Sub1 and non-Sub1 rice varieties

Introduction
Approximately 30% of India's rice field is vulnerable to crop loss from persistent floods. Of several habitats worldwide, flooding is environmental stress. Global climate change is projected to raise the extent and intensity of floods (Arnell and Liu, 2001) [2]. Rice is also the only crop cultivated in a flood-prone environment. Rainfall instability coupled with water-logging or submergence stress is a major factor affecting Indian rice yield, which is one of India's major constraints, especially i n Eastern Indian states (Sarkar *et al*., 2006 and 2009) [8, 9]. The flood-affected region is projected to have more than doubled in size from about 5% (19 million hectares) to about 12% (40 million hectares) of India's geographic area (world bank report). The key cause of harm to plants grown in submergence soil is insufficient oxygen supply to submerge d tissues as a consequence of sluggish water gas diffusion and fast soil microorganisms intake of O_2. Unlike other varieties, Rice has several adaptive features for submergence resistance. One of the features is the development of longitudinal gas space interconnection called aerenchyma that requires internal aeration between shoots and roots. Secondly, the "escape plan" includes encouraging leaf and/or stem elongation through trapped ethylene. This helps plants to restart aerobic metabolism and photosynthetic CO_2 fixation by growing their shoots above water The main morphological and physiological resistant features are sluggish leaf elongation, chlorosis, high carbohydrate reserve storage during submergence, and rapid post submergence readaptation to the aerial climate (Setter *et al*., 1997; Ito *et al*.,1999) [10, 6]. Zinc is an essential macro-micronutrient, stimulating several enzymes to conduct several metabolic reactions for crop growth and production (Prakash 2019) [7]. Low soil zinc co ntent decreases crop development and yield by stunning output, declining tillers, spikelet sterility (Hafeez *et al.* 2013; Sudha and Stalin 2015, Singh A and Singh A.K, 2020) [5, 11, 1]. Owing to submergence, flood irrigated rice is more vulnerable to Zn deficiency (Rahman *et al*., 2012) [7]. Support plant development by adding zinc. With this backdrop, the current study was conducted to select out the best zinc sulfate concentration on different rice cultivars under submergence condition for submergence adaptation and improvement in its performance.

Materials and Methods
The study was carried out during the Kharif season at the Department of Crop Physiology, Archarya Narendra Deva University of Agriculture and Technology, Kumarganj (U.P).

The experiment was Randomized Block Design of three replications and conducted in earthen pots of three separate zinc amounts and five different rice varieties.

Varieties (V) of rice and treatments (T) of Zinc sulfate detail taken for study

V1: Swarna; V2: Swarna Sub1; V3: Samba Mahsuri; V4: Samba mahsuri Sub1; V5: IR-64 Sub1; T1: 0.0 mg ZnSO4 per kg soil; T2: 5.0 mg ZnSO4 per kg soil; T3: 10 mg ZnSO4

The five varieties have been selected based on their submergence tolerance character as Swarna Sub1, Samba mahsuri Sub1, and IR-64 Sub1 are submergence tolerant whereas Swarna, Samba mahsuri are susceptible varieties. Zinc sulfate was applied in the soil at the time of sowing of seeds in the earthen pots of uniform size (25×20 cm) were used and each pot was filled with 8 kg of well-pulverized soil with a recommended dose of NPK 120:60:60 Kg/ha. Initially, five plants were raised in each pot but after thinning three plants were maintained in each pot.

Submergence treatment

The submerged condition was created by submerging pots in the cemented tank and non- submerged plants remained at the Laboratory Farm. The submerged condition was provided after 30 days of old rice seedling. The submergence duration for 15 days was created. Observation for survival, growth attributes and biochemical parameters in the pot was recorded.

Survival (%)

Plant survival was recorded after 7 days of de-submergence. Survival was indicated by the capacity of plants to produce new leaves. The difference between the number of plants per pot before submergence And 7 days after de-submergence indicate a survival pattern.

Growth observation

Growth observations were taken at four stages of the crop growth, i.e. at 30, 60, 90, 120 days after sowing (DAS).

Plant height (cm)

The plant height (cm) was measured from the base of the stem i.e. surface of the soil up to the top of the panicle. The average height was calculated over three replications consisting of two plants.

Tiller number plant^{-1}

The number of tillers per plant under each treatment was recorded by visual counting at different stages.

Dry weight (g plant^{-1})

Four healthy and uniform plants from each treatment were sampled and separated into their respective shoot and oven dried at 70^0 $\pm1^0$c till a constant weight was achieved. The weight was recorded with the help of an electronic balance.

Number of green leaves

Number of green leaves in selected plant under each treatment was recorded by visual counting at different stages.

Biochemical estimation

Determination of Chlorophyll content (SPAD value)

Chlorophyll content of leaf was directly measured from intact leaves through microprocessor plant efficiency analyzer Model: XSS / M-PEA.

Determination of Soluble Carbohydrate (mg/g dry weight)

The total carbohydrate in plant extract was estimated by the method of Yemm and Wills (1954)**.**

Statistical analyses

Data recorded on yield attributes were subjected to statistical analysis by Fisher method of analysis of variance (Fisher and Yates 1949) [3]. The significance of various treatments was judged by comparing calculated 'F' value with Fisher's 'F' value at 5 percent level, incorporate in tables, were also calculated to compare the relative performance of various treatments by using the following formula:

$$SEm\pm = \frac{EMS}{N}$$

Where, EMS is mean sum of square of error
N = total number of experimental unit level of factors

$$CD = \sqrt{\frac{2EMS}{N}} \times t(\%)$$

Where value of 't' from Fisher's table at error degree of freedom on 5% level of significance.

Results and Discussion

The result regarding survival (%), plant height (cm), tiller number per plant, dry weight per plant, number of green leaves, chlorophyll content (SPAD value), carbohydrate content under submerged condition in different submergence tolerant as well as susceptible varieties on applying different zinc level are as follows:

Survival %

Data on percent survival of different rice variety after 15 days complete submergence have been presented in table 1.1. Plant population subjected to submergence significantly reduced in all treatments. New leaf emergence was observed at 5th days of desubmergence. Maximum percent survival was recorded in ZnSO4 @10.0 mg/kg soil in swarna Sub1 (93.33%) and minimum in samba mahsuri (53.33%) under submerged condition while for the zinc level ZnSO4 @ 0.0 mg/kg soil, it was maximum in IR64 Sub1 (93.33%) and minimum in samba mahsuri (33.0%). The Sub1 gene containing varieties i.e. swarna Sub1, samba mahsuri Sub1 & IR64 Sub1 for the zinc level ZnSO4 @10.0 mg/kg soil and 0.0 mg/kg soil were 93.33%, 86.66%, 80.80% and 73.0%, 80.0%, 93.33% respectively which was higher percentage of survival than non-Sub1 gene containing varieties i.e. swarna & samba mahsuri for the zinc level ZnSO4 @10.0 mg/kg soil and 0.0 mg/kg soil were 53.33%, 53.33% and 40.0%, 33.0% respectively.

Table 1: Effect of zinc sulphate on survival (%) of Sub1 and non sub1 rice varieties exposed to submerged condition

Treatment / Varieties	Survival (%)					
	T1		T2		T3	
	A	B	A	B	A	B
V1	86.67	40.0	86.67	40.0	93.33	53.33
V2	93.33	73.0	93.33	86.66	93.33	93.33
V3	93.33	33.0	93.33	46.0	80.0	53.33
V4	100.0	80.0	100.0	86.66	93.33	86.66
V5	100.0	93.33	93.33	80.0	93.33	80.0

Here, A= Controlled condition B= Submerged condition

	Controlled	Submerged
SEm±	4.411	4.073
L.S.D at 5%	12.137	11.764

Growth attributes

Plant height (cm) at 30 DAS: The data recorded on height of plant at 30 DAS due to effect of zinc levels for rice varieties have been displayed in table 2 indicated that use of various zinc level by its increasing levels cause significant improvement in height of plants of both types varieties i.e. Sub1 & non-Sub1. Maximum plant height was recorded at zinc level @ 10.0 mg/kg soil for non- Sub1 varieties i.e. swarna (45.16 cm) & samba mahsuri (43.30 cm) and for Sub1 varieties i.e. swarna Sub1 (45.46 cm), samba mahsuri Sub1 (44.0 cm) & IR64 Sub1 (46.96 cm) in controlled condition, while maximum plant height was recorded at zinc level @ 10.0 mg/kg soil for non- Sub1 varieties i.e. swarna (43.33 cm) & samba mahsuri (43.46 cm) and for Sub1 varieties i.e. swarna Sub1 (46.0 cm), samba mahsuri Sub1 (43.60 cm) & IR64 Sub1 (45.6 cm) in submerged condition.

Plant height (cm) at 60 DAS

The data recorded on height of plant after 15 days of de-submergence (at 60 DAS) due to effect of zinc level for rice varieties for controlled and submerged condition have been summarized in table 2.

Critical analysis of data presented in table clearly depicted that use of various zinc level by its increasing levels cause significant improvement in height of plants of both types varieties i.e. Sub1 & non-Sub1.

Nevertheless maximum plant height was recorded at zinc level @ 10.0 mg/kg soil for non- Sub1 varieties i.e. swarna (57.13 cm) & samba mahsuri (52.37 cm) and for Sub1 varieties i.e. swarna Sub1 (61.0 cm), samba mahsuri Sub1 (53.15cm) & IR64 Sub1 (52.40 cm) in controlled condition, while in submerged condition, maximum plant height was recorded at zinc level @ 10.0 mg/kg soil for non- Sub1 varieties i.e. swarna (70.35 cm) & samba mahsuri (52.60 cm) and for Sub1 varieties i.e. swarna Sub1 (72.70 cm), samba mahsuri Sub1 (63.45 cm) & IR64 Sub1 (57.15 cm).

Table 2: Effect of zinc sulphate on plant height (cm) at 30 and 60 DAS of Sub1 and non Sub1 rice varieties exposed to submerged condition

Treatment / Varieties	Plant height (cm) at 30 DAS						Plant height (cm) at 60 DAS					
	T1		T2		T3		T1		T2		T3	
	A	B	A	B	A	B	A	B	A	B	A	B
V1	41.9	41.85	44.00	43.16	45.16	43.33	55.33	65.54	56.33	67.74	57.13	70.35
V2	42.4	43.13	44.93	45.16	45.46	46.00	53.44	67.94	59.03	70.30	61.00	72.70
V3	41.36	39.26	42.85	42.00	43.30	43.46	50.47	55.45	51.40	61.47	52.37	52.60
V4	41.53	40.26	43.60	42.25	44.00	43.60	49.33	59.43	51.53	59.25	53.15	63.45
V5	43.00	41.27	45.90	43.73	46.96	45.66	48.37	60.43	49.30	63.50	52.40	57.15

Here, A= Controlled condition B= Submerged condition

	Controlled	Submerged	Controlled	Submerged
SEm±	0.863	1.215	0.320	0.504
L.S.D at 5%	2.493	3.510	0.924	1.458

Plant height (cm) at 90 days:

The data recorded on height of plant after 45 days of de-submergence (at 90 DAS) due to effect of zinc level for rice varieties for controlled and submerged condition have been displayed in table 3. Critical analysis of data presented in table clearly depicted that use of various zinc level by its increasing levels cause significant improvement in height of plants of both types varieties i.e. Sub1 & non-Sub1. Nevertheless maximum plant height was recorded at zinc level @ 10.0 mg/kg soil for non- Sub1 varieties i.e. swarna (77.20 cm) & samba mahsuri (72.43 cm) and for Sub1 varieties i.e. swarna Sub1 (78.30 cm), samba mahsuri Sub1 (73.43cm) & IR64 Sub1 (69.43 cm) in controlled condition, while in submerged condition, maximum plant height was recorded at zinc level @ 10.0 mg/kg soil for non- Sub1 varieties i.e. swarna (90.58 cm) & samba mahsuri (86.74 cm) and for Sub1 varieties i.e. swarna Sub1 (84.93 cm), samba mahsuri Sub1 (84.80 cm) & IR64 Sub1 (83.27 cm).

Plant height (cm) at 120 days:

The data recorded on height of plant after 75 days of de-submergence (at harvest stage) due to effect of zinc level for rice varieties for controlled and submerged condition have been displayed in table 3. Critical analysis of data presented in table clearly depicted that use of various zinc level by its increasing levels cause significant improvement in height of plants of both types varieties i.e. Sub1 & non-Sub1. Nevertheless maximum plant height was recorded at zinc level @ 10.0 mg/kg soil for non- Sub1 varieties i.e. swarna (91.47 cm) & samba mahsuri (87.03 cm) and for Sub1 varieties i.e. swarna Sub1 (93.63 cm), samba mahsuri Sub1 (91.50cm) & IR64 Sub1 (85.60 cm) in controlled condition, while in submerged condition, maximum plant height was recorded at zinc level @ 10.0 mg/kg soil for non- Sub1 varieties i.e. swarna (114.70 cm) & samba mahsuri (111.23 cm) and for Sub1 varieties i.e. swarna Sub1 (123.30 cm), samba mahsuri Sub1 (112.23 cm) & IR64 Sub1 (109.57 cm).

Table 3: Effect of zinc sulphate on plant height (cm) at 90 and 120 DAS of Sub1 and non Sub1 rice varieties exposed to 15 days of complete submergence

Treatment/ Varieties	Plant height (cm) 90 DAS						Plant height at 120 DAS					
	T1		T2		T3		T1		T2		T3	
	A	B	A	B	A	B	A	B	A	B	A	B
V1	72.33	80.30	74.30	87.10	77.20	84.93	88.23	105.33	89.77	109.43	91.47	114.70
V2	73.97	84.75	75.20	82.37	78.30	90.58	90.60	112.33	92.30	117.77	93.63	123.30
V3	67.60	78.40	69.63	81.47	72.43	86.74	84.43	103.73	85.77	107.10	87.03	111.23
V4	68.67	81.35	70.60	84.50	73.43	84.80	88.50	105.23	89.43	108.23	91.50	112.23
V5	65.67	78.97	67.53	81.17	69.43	83.27	81.77	98.63	83.40	104.60	85.60	109.57

Here, A= Controlled condition B=Submerged condition

	Controlled	Submerged	Controlled	Submerged
SEm±	0.322	0.334	0.235	0.215
L.S.D at 5%	0.931	1.006	0.681	0.621

Number of Tiller per Plant at 30 DAS

The data recorded on number of tiller per plant after 30 DAS due to effect of zinc level for rice varieties for controlled and submerged condition have been displayed in table 4. Critical analysis of data presented in table clearly depicted that use of various zinc level by its increasing levels cause significant improvement in number of tiller per plant of both types varieties i.e. Sub1 & non-Sub1. Nevertheless maximum number of tiller per plant was recorded at zinc level @ 10.0 mg/kg soil for non- Sub1 varieties i.e. swarna (4.0) & samba mahsuri (4.33) and for Sub1 varieties i.e. swarna Sub1 (4.33), samba mahsuri Sub1 (4.66) & IR64 Sub1 (4.0) in controlled condition, while in submerged condition, maximum number of tiller per plant was recorded at zinc level @ 10.0 mg/kg soil for non- Sub1 varieties i.e. swarna (4.66) & samba mahsuri (4.66) and for Sub1varieties i.e. swarna Sub1 (5.0), samba mahsuri Sub1 (5.0) &IR64 Sub1 (5.0)

Number of Tiller per Plant 60 DAS

The data recorded on number of tiller per plant after 15 days of de-submergence (60 DAS) due to effect of zinc level for rice varieties for controlled and submerged condition have been displayed in table 4. Critical analysis of data presented in table clearly depicted that use of various zinc level by its increasing levels cause significant improvement in number of tiller per plant of both types varieties i.e. Sub1 & non- Sub1. Nevertheless maximum number of tiller per plant was recorded at zinc level @ 10.0 mg/kg soil for non- Sub1 varieties i.e. swarna (7.33) & samba mahsuri (7.66) and for Sub1varieties i.e. swarna Sub1 (7.66), samba mahsuri Sub1 (8.0) & IR64 Sub1 (6.33) in controlled condition, while in submerged condition, maximum number of tiller per plant was recorded at zinc level @ 10.0 mg/kg soil for non- Sub1 varieties i.e. swarna (8.0) & samba mahsuri (8.0) and for Sub1 varieties i.e. swarna Sub1 (8.33), samba mahsuri Sub1 (8.33) & IR64 Sub1 (7.0).

Table 4: Effect of zinc sulphate on tiller number per plant at 30 and 60 DAS of Sub-1and non-Sub-1 rice varieties exposed to 15 days of complete submergence

Treatment / Varieties	Number of tiller per plant at 30 days						Number of tiller per plant at 60 days					
	T1		T2		T1		T2		T1		T2	
	A	B	A	B	A	B	A	B	A	B	A	B
V1	3.33	3.66	3.66	4.00	4.0	4.66	6.33	7.0	6.66	7.33	7.33	8.00
V2	3.66	4.00	4.0	4.33	4.33	5.00	6.66	7.33	7.0	7.66	7.66	8.33
V3	3.00	3.66	3.66	4.00	4.33	4.66	5.66	7.00	6.66	7.33	7.66	8.00
V4	3.33	4.00	4.00	4.33	4.66	5.00	6.00	7.33	7.00	7.66	8.00	8.33
V5	3.0	3.66	3.66	4.0	4.00	5.00	5.66	6.33	6.0	6.66	6.33	7.0

Here, A= Controlled condition B= Submerged condition

	Controlled	Submerged	Controlled	Submerged
SEm±	0.207	0.221	0.196	0.249
L.S.D at 5%	0.598	0.638	0.556	0.720

Number of tiller per plant at 90 days:

The data recorded on number of tiller per plant after 45 days of de-submergence (90 DAS) due to effect of zinc level for rice varieties for controlled and submerged condition have been displayed in table 5. Critical analysis of data presented in table clearly depicted that use of various zinc level by its increasing levels cause significant improvement in number of tiller per plant of both types varieties i.e. Sub1 & non- Sub1. Nevertheless maximum number of tiller per plant was recorded at zinc level @ 10.0 mg/kg soil for non- Sub1 varieties i.e. swarna (8.0) & samba mahsuri (9.0) and for Sub1 varieties i.e. swarna Sub1 (8.66), samba mahsuri Sub1 (9.33) & IR64 Sub1 (9.66) in controlled condition, while in submerged condition, maximum number of tiller per plant was recorded at zinc level @ 10.0 mg/kg soil for non- Sub1 varieties i.e. swarna (10.0) & samba mahsuri (10.33) and for Sub1 varieties i.e. swarna Sub1 (10.66), samba mahsuri Sub1 (10.66) & IR64 Sub1 (10.66)**.**

Number of Tiller per plant at Harvest stage

The data recorded on number of tiller per plant after 75 days of de-submergence (at harvest stage) due to effect of zinc level for rice varieties for controlled and submerged condition have been displayed in table 5. Critical analysis of data presented in table clearly depicted that use of various zinc level by its increasing levels cause significant improvement in number of tiller per plant of both types varieties i.e. Sub1 & non-Sub1. Nevertheless maximum number of tiller per plant was recorded at zinc level @ 10.0 mg/kg soil for non- Sub1 varieties i.e. swarna (7.66) & samba mahsuri (7.66) and for Sub1 varieties i.e. swarna Sub1 (8.66), samba mahsuriSub1 (8.66) & IR64 Sub1 (8.0) in controlled condition, while in submerged condition, maximum number of tiller per plant was recorded at zinc level @ 10.0 mg/kg soil for non- Sub1 varieties i.e. swarna (8.33) & samba mahsuri (9.0) and for Sub1 varieties i.e. swarna Sub1 (9.66), samba mahsuri Sub1 (9.33) & IR64 Sub1 (9.0).

Table 5: Effect of zinc sulphate on dry weight (g) at 90 and 120 DAS of Sub1 and non Sub1 rice varieties exposed 15 days of complete submergence:

Treatment / Varieties	Number of tiller per plant at 90 days						Number of tiller per plant at 120 days					
	T1		T2		T3		T1		T2		T3	
	A	B	A	B	A	B	A	B	A	B	A	B
V1	8.0	9.00	8.33	9.66	8.0	10.0	6.33	7.33	7.00	8.00	7.66	8.33
V2	8.66	9.33	9.0	10.0	8.66	10.66	7.33	8.33	8.0	9.33	8.66	9.66
V3	8.33	9.33	8.66	9.66	9.0	10.33	7.0	8.33	7.33	8.66	7.66	9.0
V4	8.66	9.66	9.0	10.0	9.33	10.66	7.33	8.66	8.0	9.00	8.66	9.33
V5	8.33	10.0	8.66	10.33	9.66	10.66	7.33	7.66	7.66	8.00	8.00	9.0

Here, A= Controlled condition B= Submerged condition

	Controlled	Submerged	Controlled	Submerged
SEm±	0.237	0.258	0.221	0.261
L.S.D at 5%	0.685	0.745	0.638	0.753

Dry per plant at 30 DAS: The data recorded on dry weight per plant at 30 DAS due to effect of zinc level for rice varieties for controlled and submerged condition have been displayed in table 6. Critical analysis of data presented in table clearly depicted that use of various zinc level by its increasing levels cause significant improvement in dry weight per plant of both type varieties i.e. Sub1 & non-Sub1.

Nevertheless maximum dry weight per plant was recorded at zinc level @ 10.0 mg/kg soil for non- Sub1 varieties i.e. swarna (3.83 g) & samba mahsuri (2.8 g) and for Sub1 varieties i.e. swarna Sub1 (3.9 g), samba mahsuri Sub1 (3.3 g) & IR64 Sub1 (3.26 g) in controlled condition, while in submerged condition, maximum dry weight per plant was recorded at zinc level @ 10.0 mg/kg soil for non-Sub1 varieties i.e. swarna (3.96 g) & samba mahsuri (3.30 g) and for Sub1 varieties i.e. swarna Sub1 (4.0 g), samba mahsuri Sub1 (3.66 g) & IR64 Sub1 (3.70 g).

Dry per plant at 60 DAS

The data recorded on dry weight per plant after 15 days of de-submergence (at 30 DAS) due to effect of zinc level for rice varieties for controlled and submerged condition have been displayed in table 6. Critical analysis of data presented in table clearly depicted that use of various zinc level by its increasing levels cause significant improvement in dry weight per plant of both types varieties i.e. Sub1 & non-Sub1. Nevertheless maximum dry weight per plant was recorded at zinc level @ 10.0 mg/kg soil for non-Sub1 varieties i.e. swarna (10.76 g) & samba mahsuri (10.70 g) and for Sub1 varieties i.e. swarna Sub1 (11.76 g), samba mahsuri Sub1 (10.83 g) & IR64 Sub1 (12.13 g) in controlled condition, while in submerged condition, maximum dry weight per plant was recorded at zinc level @ 10.0 mg/kg soil for non- Sub1 varieties i.e. swarna (16.03 g) & samba mahsuri (13.83g) and for Sub1 varieties i.e. swarna Sub1 (17.13 g), samba mahsuri Sub1 (14.03 g) & IR64 Sub1 (15.7 g).

Table 6: Effect of zinc sulphate on dry weight (g) at 30 and 60 DAS of *Sub*1 and non-Sub1 rice varieties at 30 and 60 DAS exposed 15 days of complete submergence

Treatment / Varieties	Dry weight (g) at 30 Days						Dry weight (g) at 60 Days					
	T1		T2		T3		T1		T2		T3	
	A	B	A	B	A	B	A	B	A	B	A	B
V1	3.43	3.26	3.7	3.8	3.83	3.96	10.3	15.66	10.63	10.76	10.76	16.03
V2	3.50	3.3	3.8	3.93	3.9	4.0	11.33	16.66	11.50	11.76	11.76	17.13
V3	2.36	2.83	2.6	3.0	2.8	3.3	10.36	13.5	10.56	10.70	10.70	13.83
V4	2.56	3.00	2.7	3.33	3.3	3.66	10.4	14.46	10.66	10.83	10.83	14.03
V5	2.93	3.0	3.16	3.36	3.26	3.7	11.53	15.36	11.70	12.13	12.13	15.7

Here, A= Controlled condition B= Submerged condition

	Controlled	Submerged	Controlled	Submerged
SEm±	0.092	0.088	0.052	0.144
L.S.D at 5%	0.267	0.255	0.152	0.417

Dry per Plant at 90 DAS: The data recorded on dry weight per plant after 45 days of de-submergence (at 90 DAS) due to effect of zinc level for rice varieties for controlled and submerged condition have been displayed in table 7. Critical analysis of data presented in table clearly depicted that use of various zinc level by its increasing levels cause significant improvement in dry weight per plant of both types varieties i.e. Sub1 & non-Sub1. Nevertheless maximum dry weight per plant was recorded at zinc level @ 10.0 mg/kg soil for non-Sub1 varieties i.e. swarna (14.13 g) & samba mahsuri (14.90 g) and for Sub1 varieties i.e. swarna Sub1 (14.86 g), samba mahsuriSub1 (15.70 g) & IR64 Sub1 (15.83 g) in controlled condition, while in submerged condition, maximum dry weight per plant was recorded at zinc level @ 10.0 mg/kg soil for non-Sub1 varieties i.e. swarna (19.03 g) & samba mahsuri (17.50 g) and for Sub1 varieties i.e. swarna Sub1 (20.20 g), samba mahsuri Sub1 (19.76 g) & IR64 Sub1 (20.23 g).

Dry per Plant at Harvest stage

The data recorded on dry weight per plant after 75 days of de-submergence (at harvest) due to effect of zinc level for rice varieties for controlled and submerged condition have been displayed in table 7. Critical analysis of data presented in table clearly depicted that use of various zinc level by its increasing levels cause significant improvement in dry weight per plant of both types varieties i.e. Sub1 & non-Sub1. Nevertheless maximum dry weight per plant was recorded at zinc level @ 10.0 mg/kg soil for non-Sub1 varieties i.e. swarna (25.34 g) & samba mahsuri (26.34 g) and for Sub1 varieties i.e. swarna Sub1 (28.65 g), samba mahsuri Sub1 (26.36 g) & IR64 Sub1 (26.19 g) in controlled condition, while in submerged condition, maximum dry weight per plant was recorded at zinc level @ 10.0 mg/kg soil for non- Sub1 varieties i.e. Swarna (28.38 g) & samba mahsuri (30.41 g) and for Sub1 varieties i.e. swarna Sub1 (33.73 g), samba mahsuri Sub1 (33.32 g) & IR64 Sub1 (33.32 g).

Table 7: Effect of zinc sulphate on dry weight (g) at 60 and 90 DAS of Sub1 and non-Sub1 rice varieties at 30 and 60 DAS exposed 15 days of complete submergence

Treatment/ Varieties	Dry weight (g) at 90 Days						Dry weight (g) at 120 Days					
	T1		T2		T3		T1		T2		T3	
	A	B	A	B	A	B	A	B	A	B	A	B
V1	13.63	18.66	13.83	18.8	14.13	19.0	22.99	26.49	22.71	27.27	25.34	28.38
V2	14.5	19.86	14.63	20.0	14.86	20.2	24.41	31.94	27.42	31.57	28.65	33.73
V3	14.46	16.5	14.73	16.83	14.9	17.5	23.25	29.29	24.16	29.85	26.34	30.41
V4	15.36	19.36	15.56	19.5	15.7	19.76	24.08	30.47	25.71	31.07	26.36	33.32
V5	15.16	19.76	15.63	20.0	15.83	20.23	24.19	31.55	25.43	32.64	6.19	33.32

Here, A= Controlled condition B= Submerged condition

	Controlled	Submerged	Controlled	Submerged
SEm±	0.063	0.088	0.339	0.337
L.S.D at 5%	0.183	0.254	0.981	0.975

Number of green leaves per Plant at 30 DAS:

The data recorded on number of tiller per plant at 30 DAS due to effect of zinc level for rice varieties for controlled and submerged condition have been displayed in table 8. Critical analysis of data presented in table clearly depicted that use of various zinc level by its increasing levels cause significant improvement in number of green leaves per plant of both types varieties i.e. Sub1 & non-Sub1. Nevertheless maximum number of green leaves per plant was recorded at zinc level @ 10.0 mg/kg soil for non- Sub1 varieties i.e. swarna (14.0) & samba mahsuri (15.33) and for Sub1 varieties i.e. swarna Sub1 (15.0), samba mahsuri Sub1 (16.0) & IR64 Sub1 (16.0) in controlled condition, while in submerged condition, maximum number of green leaves per plant was recorded at zinc level @ 10.0 mg/kg soil for non- Sub1 varieties i.e. swarna (13.0) & samba mahsuri (14.0) and for Sub1 varieties i.e. swarna Sub1 (14.66), samba mahsuriSub1 (14.66) & IR64 Sub1 (15.33).

Number of green leaves per plant at 60 DAS

The data recorded on number of tiller per plant after 15 days of de-submergence (at 60 DAS) due to effect of zinc level for rice varieties for controlled and submerged condition have been displayed in table 8. Critical analysis of data presented in table clearly depicted that use of various zinc level by its increasing levels cause significant improvement in number of green leaves per plant of both types varieties i.e. Sub1 & non-Sub1. Nevertheless maximum number of green leaves per plant was recorded at zinc level @ 10.0 mg/kg soil for non-Sub1 varieties i.e. swarna (20.0) & samba mahsuri (24.0) and

for Sub1 varieties i.e. swarna Sub1 (21.33), samba mahsuriSub1 (25.0) & IR64 Sub1 (24.33) in controlled condition, while in submerged condition, maximum number of green leaves per plant was recorded at zinc level @ 10.0 mg/kg soil for non- Sub1 varieties i.e. swarna (16.33) & samba mahsuri (16.0) and for Sub1 varieties i.e. swarna Sub1 (17.33), samba mahsuri Sub1 (16.33) & IR64 Sub1 (18.0).

Table 8: Effect of zinc sulphate on number of green leaves at 30 and 60 DAS of Sub1 and non-Sub1 rice varieties exposed to 15 days of complete submergence:

Treatment / Varieties	Number of green leaves at 30 days						Number of green leaves at 60 days					
	T1		T2		T3		T1		T2		T3	
	A	B	A	B	A	B	A	B	A	B	A	B
V1	13.0	12.0	13.66	12.66	14.00	13.00	18.33	14.33	19.33	15.00	20.0	16.33
V2	14.33	12.66	14.66	13.33	15.00	14.66	18.66	15.00	20.33	16.33	21.33	17.33
V3	14.66	13.33	15.00	13.66	15.33	14.00	20.0	14.66	21.66	14.33	24.0	16.00
V4	15.33	13.66	15.66	14.33	16.00	14.66	22.33	14.00	23.0	15.66	25.0	16.33
V5	15.33	14.66	15.66	15.0	16.00	15.33	22.66	17.0	23.0	17.33	24.33	18.00

Here, A= Controlled condition B= Submerged condition

	Controlled	Submerged	Controlled	Submerged
SEm±	0.448	0.438	0.405	0.339
L.S.D at 5%	1.296	1.267	1.171	0.981

Number of green leaves per Plant at 90 DAS

The data recorded on number of tiller per plant after 45 days of de-submergence (at 90 DAS) due to effect of zinc level for rice varieties for controlled and submerged condition have been displayed in table 9. Critical analysis of data presented in table clearly depicted that use of various zinc level by its increasing levels cause significant improvement in number of green leaves per plant of both types varieties i.e. Sub1 & non-Sub1. Nevertheless maximum number of green leaves per plant was recorded at zinc level @ 10.0 mg/kg soil for non-Sub1 varieties i.e. swarna (28.0) & samba mahsuri (27.0) and for Sub1 varieties i.e. swarnaSub1 (31.0), samba mahsuri Sub1 (29.0) & IR64 Sub1 (32.0) in controlled condition, while in submerged condition, maximum number of green leaves per plant was recorded at zinc level @ 10.0 mg/kg soil for non-Sub1 varieties i.e. swarna (17.33) & samba mahsuri (19.0) and for Sub1 varieties i.e. swarna Sub1 (19.66), samba mahsuri Sub1 (19.66) & IR64 Sub1 (21.0).

Number of green leaves per plant at Harvest stage

The data recorded on number of tiller per plant after 75 days of de-submergence (at harvest stage) due to effect of zinc level for rice varieties for controlled and submerged condition have been displayed in table 9. Critical analysis of data presented in table clearly depicted that use of various zinc level by its increasing levels cause significant improvement in number of green leaves per plant of both types varieties i.e. Sub1 & non-Sub1. Nevertheless maximum number of green leaves per plant was recorded at zinc level @ 10.0 mg/kg soil for non- Sub1 varieties i.e. swarna (26.0) & samba mahsuri (26.0) and for Sub1 varieties i.e. swarnaSub1 (29.0), samba mahsuri Sub1 (27.66) & IR64 Sub1 (30.66) in controlled condition, while in submerged condition, maximum number of green leaves per plant was recorded at zinc level @ 10.0 mg/kg soil for non- Sub1 varieties i.e. swarna (16.0) & samba mahsuri (18.0) and for Sub1 varieties i.e. swarnaSub1 (18.0), samba mahsuriSub1 (17.66) & IR64 Sub1 (19.33).

Table 9: Effect of zinc sulphate on number of green leaves at 90 and 120 DAS of Sub1 and non-Sub1 rice varieties exposed to 15 days of complete submergence:

Treatment / Varieties	Number of green leaves at 90 days						Number of green leaves at 120 days					
	T1		T2		T3		T1		T2		T3	
	A	B	A	B	A	B	A	B	A	B	A	B
V1	26.00	16	27.66	17.0	28.0	17.33	24.33	15.0	25.66	15.66	26.0	16.0
V2	27.33	17	29.0	18.0	31.0	19.66	25.33	15.33	26.33	16.66	29.0	18.0
V3	26.33	16.66	27.0	17.33	27.0	19.0	25.0	15.66	25.33	16.0	26.0	17.66
V4	28.0	17	29.0	18.66	29.0	19.66	26.33	16.0	27.33	17.0	27.66	18.0
V5	30.0	20	30.66	20.33	32.0	21.0	28.0	18.33	29.0	18.66	30.66	19.33

Here, A= Controlled condition B= Submerged condition

	Controlled	Submerged	Controlled	Submerged
SEm±	0.319	0.377	0.274	0.300
L.S.D at 5%	0.923	1.089	0.793	0.868

Biochemical Parameters

Chlorophyll content before submergence

The data recorded on chlorophyll content due to effect of zinc level for rice varieties for controlled and submerged condition have been displayed in table.

Critical analysis of data presented in table clearly depicted that use of various zinc level by its increasing levels cause significant improvement in chlorophyll content of both types varieties i.e. Sub1 & non-Sub1. Nevertheless maximum chlorophyll content was recorded at zinc level @ 10.0 mg/kg soil for non- Sub1 varieties i.e. swarna (12.40 SPAD value) & samba mahsuri (10.60 SPAD value) and for Sub1 varieties i.e. swarna Sub1 (12.66 SPAD value), samba mahsuriSub1 (10.96 SPAD value) & IR64 Sub1 (12.60 SPAD value) in controlled condition, while in submerged condition, maximum days to chlorophyll content was recorded at zinc level @ 10.0 mg/kg soil for non- Sub1 varieties i.e. swarna (12.25 SPAD value) & samba mahsuri (11.10 SPAD value) and for Sub1 varieties i.e. swarna Sub1 (13.63 SPAD value), samba mahsuri Sub1 (12.26 SPAD value) & IR64 Sub1 (12.83 SPAD value).

Chlorophyll content after submergence

The data recorded on chlorophyll content due to effect of zinc level for rice varieties for controlled and submerged condition have been displayed in table. Critical analysis of data presented in table clearly depicted that use of various zinc

level by its increasing levels cause significant improvement in chlorophyll content of both types varieties i.e. Sub1 & non-Sub1. Nevertheless maximum chlorophyll content was recorded at zinc level @ 10.0 mg/kg soil for non- Sub1 varieties i.e. swarna (14.73 SPAD value) & samba mahsuri (16.90 SPAD value) and for Sub1 varieties i.e. swarna Sub1 (15.13 SPAD value), samba mahsuriSub1 (18.53 SPAD value) & IR64 Sub1 (19.66 SPAD value) in controlled condition, while in submerged condition, maximum chlorophyll content was recorded at zinc level @ 10.0 mg/kg soil for non- Sub1 varieties i.e. swarna (10.23 SPAD value) & samba mahsuri (10.20 SPAD value) and for Sub1 varieties i.e. swarna Sub1 (10.66 SPAD value), samba mahsuri Sub1 (11.80 SPAD value) & IR64 Sub1 (9.46 SPAD value).

Table 10: Effect of zinc sulphate on Chlorophyll content of Sub1 and non-Sub1 rice varieties exposed to 15 days of complete submergence:

Treatment / Varieties	Chlorophyll content (SPAD value) (Before submergence)						Chlorophyll content (SPAD value) (After Submergence)					
	T1		T2		T3		T1		T2		T3	
	A	B	A	B	A	B	A	B	A	B	A	B
V1	10.90	10.71	11.83	11.02	12.40	12.25	13.46	8.76	13.60	9.25	14.73	10.23
V2	11.66	12.86	12.40	13.23	12.66	13.63	14.23	9.40	14.63	10.33	15.13	10.66
V3	9.30	9.93	10.13	10.73	10.60	11.10	14.33	9.16	14.96	9.93	16.90	10.20
V4	10.16	11.25	10.63	11.50	10.96	12.26	17.53	10.13	17.70	10.73	18.53	11.80
V5	11.66	11.83	12.0	12.13	12.60	12.83	15.84	8.23	18.53	8.70	19.66	9.46

Here, A= Controlled condition B= Submerged condition

	Controlled	Submerged	Controlled	Submerged
SEm±	0.175	0.151	0.165	0.222
L.S.D at 5%	0.506	0.438	0.447	0.642

Carbohydrate content before submergence

The data recorded on carbohydrate content due to effect of zinc level for rice varieties for controlled and submerged condition have been displayed in table. Critical analysis of data presented in table clearly depicted that use of various zinc level by its increasing levels cause significant improvement in carbohydrate content of both types varieties i.e. Sub1 & non-Sub1. Nevertheless maximum carbohydrate content was recorded at zinc level @ 10.0 mg/kg soil for non-Sub1 varieties i.e. swarna (62.02 mg/g dry wt.) & samba mahsuri (67.23 mg/g dry wt.) and for Sub1 varieties i.e. swarna Sub1 (64.85 mg/g dry wt.), samba mahsuri Sub1 (68.03 mg/g dry wt.) & IR64 Sub1 (62.26 mg/g dry wt.) in controlled condition, while in submerged condition, maximum carbohydrate content was recorded at zinc level @ 10.0 mg/kg soil for non- Sub1 varieties i.e. swarna (64.49 mg/g dry wt.) & samba mahsuri (69.81 mg/g dry wt.) and for Sub1 varieties i.e. swarna Sub1 (66.26 mg/g dry wt.), samba mahsuri Sub1 (71.72 mg/g dry wt.) & IR64 Sub1 (63.21 mg/g dry wt.).

Carbohydrate content after submergence

The data recorded on carbohydrate content due to effect of zinc level for rice varieties for controlled and submerged condition have been displayed in table. Critical analysis of data presented in table clearly depicted that use of various zinc level by its increasing levels cause significant improvement in carbohydrate content of both types varieties i.e. Sub1 & non-Sub1. Nevertheless maximum carbohydrate content was recorded at zinc level @ 10.0 mg/kg soil for non-Sub1 varieties i.e. swarna (65.02 mg/g dry wt.) & samba mahsuri (71.30 mg/g dry wt.) and for Sub1 varieties i.e. swarna Sub1 (69.85 mg/g dry wt.), samba mahsuri Sub1 (70.03 mg/g dry wt.) & IR64 Sub1 (66.26 mg/g dry wt.) in controlled condition, while in submerged condition, maximum carbohydrate content was recorded at zinc level @ 10.0 mg/kg soil for non- Sub1 varieties i.e. swarna (43.56 mg/g dry wt.) & samba mahsuri (34.61 mg/g dry wt.) and for Sub1 varieties i.e. swarna Sub1 (39.54 mg/g dry wt.), samba mahsuri Sub1 (46.25 mg/g dry wt.) & IR64 Sub1 (32.82 mg/g dry wt.).

Table 11: Effect of zinc sulphate on carbohydrate content of Sub1 and non-Sub1 rice varieties exposed to 15 days of complete submergence:

Treatment / Varieties	Carbohydrate content (mg per dry wgt) (Before submergence)						Carbohydrate content (mg per dry wgt) (After submergence)					
	T1		T2		T3		T1		T2		T3	
	A	B	A	B	A	B	A	B	A	B	A	B
V1	59.03	60.59	60.47	62.28	62.02	64.49	61.45	40.40	63.47	41.75	65..02	43.56
V2	61.58	63.84	62.83	65.06	64.85	66.26	65.28	36.67	67.83	38.37	69.85	39.54
V3	64.17	66.96	66.48	68.93	67.23	69.81	67.34	32.83	69.48	33.80	71.23	34.61
V4	65.79	67.98	66.61	69.76	68.03	71.72	68.54	42.73	70.61	44.40	70.03	46.25
V5	57.30	59.92	60.68	61.09	62.26	63.21	60.54	31.52	63.68	32.56	66.26	32.82

Here, A= Controlled condition B= Submerged condition

	Controlled	Submerged	Controlled	Submerged
SEm±	0.300	0.292	0.292	0.299
L.S.D at 5%	0.866	0.844	0.845	0.864

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