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Effect of Drought Stress on Growth and Yield Attributes of Paddy

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ABSTRACT

The present study was carried out in the Shed-net house of the Krishi Vigyan Kendra, Kalahandi during Rabi 2016-17.The objective of the present endeavour was to screen 6 number of rice varieties viz. Heera(V_1), Sneha(V_2), Kalinga-III(V_3), Subhadra(V_4), Rudra(V_5) & Sankar (V_6) (early group,75-85 days) for higher photosynthetic efficiency with higher productivity under simulated moisture stress conditions. The experiment was laid out in a factorial CRD with three stress treatments and three replications. The study revealed that moisture stress imposed at different growth stages reduced plant height, tiller number, leaf area, specific leaf weight in all the varieties. However, the variation among them has found to be statistically significant. It was found that the significant variation existed among the varieties under favourable conditions (non stress).Which might be due to relative difference in their genetic potential, when all these varieties were subjected to moisture stress condition the grain yield reduced significantly. However, the magnitude of reduction among the varieties was different. Varieties like V_5, V_3 and V_1 suffered least; while the varieties like V_4, V_6 and V_2 suffered most due to adverse stress condition. In general, there was about 42 % reduction in yield (per plant basis) and 17 % in harvest index when subjected to stress condition. Similarly, expression of yield loss on unit area basis (kg/ha) the same was found to be 19 % at flowering. The reduction in grain yield was due to stress attributed to reduction in panicle length, panicle weight and weight of the grain. Hence the above mentioned yield attributing character should primarily be taken as selection criteria for drought tolerance of rice cultivars.

Key words: *Drought stress, effective tillers, panicle length, fertile grain and harvest index*

INTRODUCTION

Rice is the predominant food crop of the world only second to wheat, in particular, the most predominant of Southeast Asia, and of course India. Rice being the main stay of 50 % of the global population bears a testimony to its importance while planning for food security of the ever-burgeoning population of the World.

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Since, land area and other natural resources are becoming increasingly scarce, for increasing crop production, greater emphasis is being laid on increasing productivity per unit of land area, unit of input and unit of time, and it is also for the rice crop. Constraints to rice production are many, but predominant is moisture stress, as more than 70 % of the rice grown in India is rainfed and such rainfed dryland occupying 6.0 million hectares. Productivity of rice is as low as around 60-75 % lower than in irrigated conditions. The rainfed rice is most prone to vagaries of nature. Rains during the growing season are often erratic and its distribution is highly uneven, as a result the crop faces moisture stress of different types and intensities. Moisture stress frequently occurs, either at one or more phenological stage of the upland rice crop raised under rainfed condition. From the meteorological history of India, it is imminent that the country faces a drought almost every three years. And the most affected is the rice crop, owing to its requirement of wetland ecosystem in general. There are large number of morphological and physiological traits associated with plants growing naturally in arid environment, that it is believed to confer drought resistance on these plants. Identification of these traits is necessary to incorporate such desirable traits in the breeding programme[1]. Although the ability to tolerate drought and have acceptable yields is limited among cultivars within a species, there are considerable differences among cultivars that allow them to avoid drought. Drought may be avoided by matching crop phenology with periods during the cropping season when water supply is abundant. This approach has been an effective tool for crops grown in monsoonal climates where they are sown at the beginning of wet season and mature before dry season[2]. But the strategy often fails owing to the erratic monsoon during these days. This study has been taken up with the main objective to have a greater insight into this physiological and biochemical basis of drought tolerance in rice which would come in handy in designing the crop ideotypes for drought prone environments.

MATERIALS AND METHODS

This experiment was conducted in Rabi 2016-17 in a wire net house of the Krishi Vigyan Kendra, Kalahandi in completely randomized design (CRD). Sowing of seeds was done in cement pots containing Mixture of soil and FYM (4:1). The holes of pots were partially closed to ensure proper drainage during watering the pots. The soil was treated with chloropyriphos dust before sowing to protect the seeds against the white ants. Plant protection measures and irrigation schedules were taken as and when required. The sowing was done on 1st January, 2016 in the cement pots at a rate of 10 seeds per pot. After two weeks of sowing only 5 healthy seedlings were allowed to grow thinning the rest. Well decomposed farm yard manure and recommended doses of chemical fertilizers were applied to experimental pots. The various intercultural operations leading to loosening of soil, weeding and thinning were done 15 days after sowing of the crop followed by second weeding. Seeds were treated with Thiram at the rate of 3 gm/kg of seed before sowing in order to protect the crop from seed borne diseases. Recommended pesticides were applied as and when required.

Table 1 Details of varieties used

Symbol	Varieties
V_1	Heera(V_1)
V_2	Sneha(V_2)
V_3	Kalinga-III (V_3)
V_4	Subhadra(V_4)
V_5	Rudra(V_5)
V_6	Sankar (V_6)

Water stress level

No water stress (control)	N_S
Stress (with holding irrigation at flowering stage)	S_1
Stress at flowering	S_2

Control pots were irrigated regularly maintaining soil moisture at field capacity throughout the cropping period.

S1: Water stress at tillering stage (Irrigation was withheld till the temporary wilting of the plants).

S2: Water stress at flowering stage (Irrigation was withheld at flowering stage to the same replication till the temporary wilting of the plants).

Five hills were uprooted from each treatment at different growth stages and the following observations were recorded, computed and presented in tabulated form.

Morphological Studies

Five hills were uprooted from each treatment at different growth stages and the following observations were recorded, computed and presented in tabulated form in the subsequent chapter.

Plant height

Plant height was measured at tillering, PI, flowering and harvest stages for each treatment. At the beginning plant heights were also recorded for each variety at 30 days after sowing which was considered same for all treatments for the varieties to be tested. The height from the base of the stem up to the collar region of the topmost leaf was taken in all stages except harvest stage where the height to the tip of the panicle was taken as the terminal point.

Number of tillers per hill

The number of tillers was recorded for each stage. However at harvest stage only the number of panicle bearing tillers were considered as tillers.

Leaf area per hill (cm^2 g^{-1})

The leaf area was measured from the measurement of maximum length and maximum breadth of the leaf and factor "K". suggested by Palaniswamy and Gomez (1974).

$$K = \frac{\text{Actual leaf area in cm}^2}{(\text{Length (L)} \times \text{Max. Breadth of leaf) in cm}^2}$$

Then the factor "Y" was found for the known sample and multiplied with the bulk leaf dry weights for obtaining the leaf area.

$$Y = \frac{\text{Actual leaf area in cm}^2}{\text{Leaf dry weight in g}}$$

Relative Water Content (RWC) (g g-1 week-1)

The RWC of leaves was determined at tillering, panicle initiation and flowering stages. Fresh weights (FW) of leaf samples were taken and they were drowned in distilled water in covered petridishes and kept overnight in a BOD incubator at 23 $\pm$ 5^0C so as to attain turgidity. The turgid weights (TW) were taken and the samples were oven dried for 48hrs at 80 ^{0}C in hot air oven. Dry weights were recorded and the RWC was determined using the following formula given by Weatherly[7].

$$\text{RWC (\%)} = \frac{FW - TW}{TW - TW} \times 100$$

Specific Leaf Weight (SLW) (mg cm^2)

The SLW was calculated according to the following formula

$$\text{SLW} = \frac{W_L}{A}$$

Where,

W_L = Total leaf dry weight

A = Total leaf area of plant

Relative Growth Rate (RGR)

The relative growth rate was calculated according to the formula given by West *et al.* and expressed as g g^{-1} $week^{-1}$.

$$\text{RGR} = \frac{\ln W_2 - \ln W_1}{(t_2 - t_1)}$$

Where,

W_1 = Dry weight of the whole plant at the start of the period

W_2 = Dry weight of the whole plant at the end of the period

$(t_2 - t_1)$= Period in week between initial and final observations

Yield attribute studies

After the crop was harvested various yield attributes were recorded. For this five hills were randomly sampled and observations were made, on the following characters: Total number of grains, number of bold and number of half-filled grains and number of chaffs per panicle. Ten panicles were randomly sampled and the spikelets extracted. Then the bold grains, half-filled grains and chaffs were segregated and counts and weights of bold grains were taken for each treatment.

1000 grain wt.

Thousand bold grains were counted and respective weights were taken.

Harvest Index

This being the ratio between economic yield and the biological yield (above ground part) was determined using the formula given below.

$$\text{Harvest Index (HI)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

RESULTS AND DISSCUSSION

Plant height

Plant height of different rice varieties was recorded at 3 different times viz., tillering, PI and flowering stages (Table 2). Data envisaged that the varieties varied significantly among themselves in respect of this character, both at stress and non-stress conditions. The overall mean values indicated that V_6 registered maximum plant height followed by V_5, V_4 and V_3. The minimum value obtaining V_1 in non-stress and stress the plant height varied between 35.30 to 30.8 cm and 32.6 to 28.93 cm respectively at tillering stage. At PI and flowering the same variety V_6 excelled over other varieties and lowest recorded in V_1 and V_2 respectively. In general, plant height decreased owing to imposition of moisture stress irrespective of growth stages. However, the extent of decreases due to stress in all most all varieties was subtle even if the interaction between V x S is significant. The effect of stress among the growth stages was found to be minimum so far as the reduction in plant height was concerned among the varieties. The resent finding corroborates the research highlights of different workers in respect of this morphological traits of rice.

Tillering

Data on the effect of moisture stress on tiller numbers have been presented in **Table 2**. The number of tillers per hill reduced when the rice plants were subjected to moisture stress at different growth stages. Maximum reduction was recorded in plants exposed to stress at flowering. On the other hand, the impact of stress at tillering stage was not significant when number of productive tillers were taken into account. Variety V_6 produced maximum number tillers followed by V_5. The lowest numbers of tillers were produced in variety V_2 at tillering stage. On the other hand at flowering stage the same trend was maintained with slightest exception. It was evident that significant variation existed among the varieties in respect of the character both at stress and non-stress conditions. The extent of reduction due to stress was almost same in all the varieties at both the stages. It has been reported that tiller production is much more sensitive and more over not all the tillers produced survive to bear ears and the tiller death phase were reported to be sensitive to water stress. Chandra *et al*., also reveal the similar reports in dry environment.

Leaf area

Data on leaf area of 6 number of rice varieties were depicted in Table no. 2 at tillering and at flowering stages. It was observed that leaf area decreased in all the varieties at both the stages studied. The highest leaf area was observed in V_1 followed by V_2 and V_3 at tillering, while at flowering stage the same was observed in V_1 followed by V_3 and V_2 as was evident from their means (NS/S). The lowest leaf area was observed in V_4 and V_6 respectively. The decrease in leaf area was to the tune of 40 % and 23 % respectively at tillering flowering stage under stress environment. A significant variation was also seen due to the interaction of V x S. It is worthy to mention here that leaf expansion is particularly sensitive to water stress. Hence, reduction in leaf was with concomitant reduction in area of photosynthetic tissue as well photosynthesis suffered a great deal when plant experience water stress. It is an established fact that plant and organ size exercise a major control over plant and crop water use. Thus, small plant of small leaf area and leaf area index use relatively less water and are expected to enter a state of plant water deficit later than large plant of greater leaf area index. On being subjected to water stress, plant reduces their size and leaf area through stress responsive system that is not within the domain of the basis genetic control of the plant size.

Specific leaf weight (SLW)

Data presented in Table 4, it was evident from the present finding that significant variation existed among the rice varieties irrespective of stages. Among the varieties Kalinga-III (V_3) recorded highest specific leaf weight followed by Sneha (V_2) and Rudra (V_5), whereas the lowest value was obtained in Heera (V_1) at tillering. The effect of stress on SLW was found to be spectacular as in both the stages in the entire varieties registered decreasing trend. So far as the interaction between VxS was concerned, it was found to be statistically significant at both the stages. However the extent of reduction in leaf dry wt. was more pronounced at tillering (17%) compared to flowering stage (24%) than that of their respective control. This indicates the leaf phenology is much more sensitive at tillering compared to the latter. In contrast Chauhan *et al.* implicated that water deficit at booting and anthesis significantly decreased effective leaf area in rice.

Relative growth rate (RGR)

Relative growth rate was computed between 44 and 58 days after sowing of different rice varieties which appeared in Table 4. RGR express the dry weight increased in time interval in relation to the initial weight. The lone observation was taken between tillering and flowering stage in all the varieties grown under moisture deficit condition. The growth rate decreased in general in all the varieties with few exceptions might be due to sampling errors. Since the RGR response to drought presented from the net assimilation rate, it is quite obvious the decrease in photosynthesis that results in decrease in NAR and subsequently the RGR. Some of the varieties maintain substantial RGR grown under stress condition. The varieties were V_4 (NS -0.12, S -0.11), V_2 (NS – 0.12, S = 0.12), V3 (NS -011, S – 0.10), . The most decrease was obtained in V_6, V_5, $V_1$when stress was imposed. Similar finding were obtained by Xu and Zhou and Ichwartoari *et al.* In our study the reduction in RGR due to stress was to the tune of 67 to 19%.

Relative water content (RWC)

Several Scientists have propounded maintenance of higher leaf water potential /relative water content (RWC) as an avoidant mechanism by plants to resist the impact of water deficit. In the present experiment water deficit invariably affected the water status of plant as was evident from the Table 4. Out of the varieties tested V_5, V_6 and V_2 maintained relatively higher water content under moisture deficit condition at tillering stage, while at flowering V_5, V_4 and V_2 varieties were found superior to rest of the varieties. The most decrease in RWC at tillering and flowering was V_3, V_2, V_1 and V_5 respectively. The extent of reduction in RWC at tillering was 13% while it was 11% at flowering .Significant variation in their interaction (V x S) was also manifested at both the stages in the present endeavors.

Yield and yield attributes

Panicle characteristics

It was note worthy from the present finding that water stress reduced the number of panicles/hill to a great extent compared to panicle length in Table no. 3. The number of panicles under non-stress varied within a range of 6 to 7 while it was 5.5 to 6.2 when stress was imposed. On contrary panicle length varied between 17 to 26cm and 16 to 25cm, respectively. Water stress reduced the number of panicle by a value 4 to 5 while it was 3 to 5cm in case of panicle length. Computation of the value revealed that the decrease in number of panicle per hill & panicle length due to water stress was to the tune of 48 and 8 % respectively.

Contrastingly the number of grains per panicle significant reduced with concomitant increase in number of chaffs in all the varieties owing to stress imposition (Table 3) Some of the varieties suffered a great deal so far as grains per panicle is concerned varieties like V_5, V_6 & V_1 produced significantly lower number of grains under unfavourable condition i.e. water stress. Out of the left over varieties V_2, V_3 and V_4 recorded sustainable grain production under the same condition. Other varieties behave moderately under water stress condition. In general the susceptible varieties produced more number of chaffs even to the tune of 46 numbers per panicle as compared to 9 numbers being the lowest of all.

There was 14 % reduction in fertile grain number due to stress while increase in chaffy grains was found to be 61 % due to the same.

Though the varieties differed significantly in their test wt. the same was not influenced by moisture stress significantly. The test weights were simply their genetic manifestation.

Yield and harvest Index

Keeping the above facts in mind the grain yield as well as the harvest index were computed and presented in Table 3 It was noticed that the significant variation existed among the varieties under favourable conditions (non stress). Which might be due to relative difference in their genetic potential, when all these varieties were subjected to moisture stress condition the grain yield reduced significantly. However, the magnitude of reduction among the varieties was different. Varieties like Rudra, Kalinga-III, and Heera suffered least; while the varieties like V_4, V_6 and V_2 suffered most due to adverse stress condition. In general, there was about 42 % reduction in yield (per plant basis) and 17 % in harvest index when subjected to stress condition. Similarly, expression of yield loss on unit area basis (kg/ha) the same was found to be 19 % at flowering. The reduction in grain yield was due to stress attributed to reduction in panicle length, panicle weight and weight of the grain. Hence the above mentioned yield attributing character should primarily be taken as selection criteria for drought tolerance of rice cultivars.

	Plant Height									Number of effective tillers plant-1						leaf area cm2 hill-1					
	Tillering			PI			Flowering			Tillering stage			Flowering			Tillering stage			Flowering		
Varieties	NS	S	M	NS	S	M	NS	S	M	NS	S	M	NS	S	M	NS	S	M	NS	S	M
V1	31.20	29.33	30.27	62.70	58.30	60.50	68.27	65.37	66.82	9.00	7.00	8.00	6.00	6.00	6.00	10.42	4.20	7.31	10.52	9.90	10.21
V2	30.87	29.27	30.07	65.43	60.60	63.02	70.00	65.97	67.98	8.00	7.00	7.50	6.00	5.50	5.75	6.84	5.40	6.12	8.44	6.45	7.45
V3	33.50	28.93	31.22	67.33	63.20	65.27	76.47	67.93	72.20	11.00	8.00	9.50	6.50	6.00	6.25	8.11	3.33	5.72	11.30	7.70	9.50
V4	32.20	30.27	31.23	70.83	63.97	67.40	75.70	70.93	73.32	11.00	7.00	9.00	6.53	5.50	6.02	4.92	3.26	4.09	5.57	4.40	4.99
V5	33.10	32.27	32.68	72.67	62.13	67.40	76.40	75.53	75.97	10.00	8.00	9.00	6.00	5.50	5.75	3.27	4.22	3.75	6.65	4.64	5.65
V6	35.30	32.67	33.98	73.53	64.70	69.12	80.00	76.27	78.13	12.00	9.67	10.83	6.83	6.20	6.52	6.71	3.73	5.22	6.20	4.33	5.27
Mean	32.69	30.46		68.75	62.15		74.47	70.33		10.17	7.78		6.31	5.78		6.712	4.024		8.114	6.237	
	V	S	V x S	V	S	V x S	V	S	V x S	V	S	V x S	V	S	V x S	V	S	V x S	V	S	V x S
Sem	0.849	1.471	2.080	0.897	1.554	2.198	0.804	1.393	1.970	0.859	0.496	1.214	0.168	0.097	0.237	0.098	0.056	0.138	0.029	0.017	0.042
CD 5%	2.643	4.578	6.474	2.793	4.837	6.841	2.503	4.335	6.130	2.672	1.543	3.779	0.522	0.301	0.738	0.304	0.175	0.429	0.091	0.053	0.129

	Panicle length			No. of panicle hill^{-1}			Fertile grains			Chaffy grains			1000 grain weight			Harvest index		
Varieties	NS	S	M	NS	S	M	NS	S	M	NS	S	M	NS	S	M	NS	S	M
V1	23.87	22.33	23.10	6.00	6.00	6.00	118.33	104.67	111.50	6.00	9.33	7.67	23.50	22.70	23.10	43.34	37.54	40.44
V2	26.43	25.17	25.80	6.00	5.50	5.75	134.67	112.00	123.33	16.67	46.00	31.33	28.03	27.43	27.73	35.09	30.69	32.89
V3	26.87	21.43	24.15	6.50	6.00	6.25	77.67	60.33	69.00	7.00	11.67	9.33	23.01	22.27	22.64	47.36	36.30	41.83
V4	17.23	16.27	16.75	6.53	5.50	6.02	79.67	65.67	72.67	8.00	13.00	10.50	23.70	22.60	23.15	41.17	31.94	36.56
V5	21.40	20.50	20.95	6.00	5.50	5.75	92.33	87.33	89.83	9.67	30.67	20.17	18.63	37.40	28.02	44.15	39.66	41.91
V6	20.07	19.67	19.87	6.83	6.20	6.52	72.33	60.33	66.33	4.00	24.33	14.17	23.50	22.37	22.93	42.27	33.94	38.11
Mean	22.64	20.89		6.31	5.78		95.83	81.72		8.56	22.50		23.40	25.79		42.23	35.01	
	V	S	VxS	V	S	VxS	V	S	VxS	V	S	VxS	V	S	VxS	V	S	VxS
Sem	23.87	22.33	23.10	6.00	6.00	6.00	11.332	6.543	16.026	5.117	2.954	7.236	6.094	3.518	8.618	0.029	0.017	0.041
CD 5%	26.43	25.17	25.80	6.00	5.50	5.75	35.267	20.362	49.876	15.925	9.194	22.521	18.96	10.95	26.82	0.090	0.052	0.127

	Relative growth rate (RGR) ($g\ g^{-1}$ leaf DW $week^{-1}$)			Specific leaf weight (SLW)(mg dm^{-2})						Relative water content (RWC) (%)					
	Tillering stage			Tillering stage			PI Stage			Tillering			Flowering		
Varieties	**NS**	**S**	**M**	**NS**	**S**	**M**	**NS**	**S**	**M**	**NS**	**Stress**	**Mean**	**NS**	**Stress**	**Mean**
V1	0.12	0.11	0.12	168.3	165.6	167.0	396.6	298.3	347.5	90.63	76.53	83.58	85.40	70.15	77.78
V2	0.11	0.10	0.10	306.3	268.3	287.3	637.0	552.0	594.5	97.19	80.39	88.79	88.54	75.52	82.03
V3	0.11	0.10	0.11	317.00	287.0	302.0	369.3	348.6	359.0	98.14	77.81	87.97	89.45	71.30	80.38
V4	0.20	0.20	0.20	230.33	148.3	189.3	396.33	153.3	274.8	87.13	75.66	81.39	80.10	75.95	78.03
V5	0.33	0.32	0.33	308.00	191.33	249.67	347.00	240.0	293.5	86.65	81.99	84.32	78.28	76.45	77.37
V6	0.26	0.26	0.26	245.3	237.6	241.5	375.6	283.3	329.5	86.44	81.80	84.12	79.31	74.81	77.06
Mean	0.19	0.188		262.55	216.38		396.67	298.3		91.03	79.03		83.51	74.03	
	V	S	V x S	V	S	V x S	V	S	V x S	V	S	V x S	V	S	V x S
Sem	0.003	0.002	0.004	25.738	14.860	36.39	49.92	28.82	70.60	3.011	1.738	4.258	0.050	0.029	0.071
CD 5%	0.008	0.005	0.012	80.100	46.24	113.27	155.37	89.70	219.7	9.370	5.410	13.251	0.157	0.090	0.221

CONCLUSION

It was found that the significant variation existed among the varieties under favourable conditions (non stress).Which might be due to relative difference in their genetic potential, when all these varieties were subjected to moisture stress condition the grain yield reduced significantly. However, the magnitude of reduction among the varieties was different. Varieties like V_5, V_3 and V_1 suffered least; while the varieties like V_4, V_6 and V_2 suffered most due to adverse stress condition. In general, there was about 42 % reduction in yield (per plant basis) and 17 % in harvest index when subjected to stress condition. Similarly, expression of yield loss on unit area basis (kg/ha) the same was found to be 19 % at flowering. The reduction in grain yield was due to stress attributed to reduction in panicle length, panicle weight and weight of the grain. Hence the above mentioned yield attributing character should primarily be taken as selection criteria for drought tolerance of rice cultivars.

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