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Impact of short term water logging on flowering, fruit setting, yield and yield attributes in tomato (*Solanum lycopersicum* L. Mill)

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Abstract
A pot experiment with four off season *kharif* varieties of Odisha were arranged in a factorial completely randomized design with an aim to investigate the effect of waterlogging on the reproductive phase and yield of tomato and to find out the best performing cultivar out of four. 45 days old tomato seedlings were subjected to short term waterlogging stress of 15 cm depth stagnant water for 1, 2 and 3 days respectively. A reduction of about 50% in flowering and fruiting were observed in susceptible varieties, where as in case of U. Kumari it was about 44% under 2 days of waterlogging. Short term waterlogging strongly influence the flowering and fruit maturity irrespective of any cultivars. Fruit setting percentage were also decreased in all the cultivars over control plants. U. Kumari was observed with highest fruit setting percentage of 73.6% and 71.9% under 1 and 2 days of waterlogging under stress about 50-60% reduction in yield were also observed.

Keywords: waterlogging, tomato, days to flowering, fruit weight, fruit setting percentage, HI

Introduction
Tomato is one of the important vegetable crops of special economic importance in the horticultural industry. It is a moderate nutritional crop and is considered as important source of vitamin C and minerals. The tomato fruit contains significant amount of lycopene, beta carotene, Magnesium, Potassium, niacin and riboflavin. It has antioxidant properties and potential beneficial health effects (Zhang *et al*., 2010) [17]. About 150 million tons of tomatoes were produced in the world. India is the 2nd largest producer of tomatoes, producing nearly 17.5 million tons and the area under cultivation was 5.4 million ha with average production of 15.68 qha^{-1}. Andhra Pradesh is the highest producer of tomato in India. Odisha ranks 6 in tomato production among the states. Odisha's share in tomato production is 6.17% in 2016-17 (Department of Agriculture and Co-operation). Water logging is a major environmental stress that severely limits the crop productivity. It may result due to heavy rain fall, faulty irrigation, unlevelled land, poor drainage, or heavy soil texture. It is estimated that about 13% of the global land area and 16% of the tomato areas in production worldwide are prone to the risk of flooding and water logging (Ahsana *et al.*, 2007) [1] As a consequence of disturbed physiological functioning, vegetative and reproductive growth of tomato plant is negatively affected by water logging (Kozlowski, 1997; Gibbs and Greenway, 2003) [9, 5]. Under root hypoxia due to lack of oxygen availability results yellowing and death of the leaves from the lower ones to the stem, epinasty in tomato leaves (Kramer, 1951), decrease in the nitrogen concentration in shoots of plant Jackson (2005) [8]. Seedlings can occur rapidly after the onset of water logging and precede leaf chlorosis (Drew 1977; Wang *et al.*, 1996) [16] and consequently reduces shoot and root growth, dry matter accumulation, and final yield (Kozlowski, 1997; Drew, 1992, Malik *et al.*, 2002) [9, 13]. Production of high amount of ethylene under stress reduces flower bud initiation and cause fruit abscission (Grichko and Glick 2001) [6]. Reduction in metabolism and dry matter partitioning is a major cause of poor fruit growth. Thus it results into a concomitant reduction in fruit yield and harvest index (Kuo *et al.*, 1982 Bennett 2003 Heeb *et al.*, 2005) [11, 2, 7]. Reduction in fruit weight and size were more pronounced in sensitive cultivars than resistance one (Lin *et al.*, 2004) [12]. During off seasons waterlogging is a major problem in a subtropical country like India, and under Odisha agro climatic conditions tomato production is high during cooler months (Octeber-February) but in *Kharif* or Off-season (June-July) planting shows a detrimental decrease in production due to stagnant water in heavy rains, which cause a high hike in price due to less supply. In sight to the above fact screening and identification of off season and high yielding tomato cultivar under short term waterlogging is the major objective of this experiment.

Materials method

An experiment was conducted in the net house of Department of plant physiology, Orissa University of agriculture and technology, Bhubaneswar during *kharif* 2017 with four popular off-season OUAT released varieties.

1. Utkal Pallavi
2. Utkal Dipti
3. Utkal Kumari
4. Utkal Pragyan

They were arranged in a Factorial completely randomizes design (FCRD) and replicated thrice to observe two factor interactions. 4 sets of pots were used to grow tomato seedlings having 4 different varieties. One set of pot with all the four tomato varieties kept as such under normal condition in net house with single seedling. The other three sets having one plant each were imposed with standing water of 15cm depth at 45 DAT for 0(S0), 1(S1), 2(S3) and 3(S4) days respectively. After withdrawal of stress the plants were allowed to grow under normal condition till it attended reproductive phase, but all plants under 3 days of waterlogging were died.

Days to flowering and fruit maturity

Days to flowering was counted as number of days taken from sowing to at least one flower opening. Number of days taken for maturity of at least one fruit from the day of sowing was considered as days to fruit maturity (IPGRI, 1996).

Number of flowers and fruits per plant

Total number of flowers and fruits were counted at the time of anthesis and harvesting of each treatment from each variety and the percent decrease were calculated with respect to control plants.

Average fruit weight (g)

Total fruit weight were recorded for each variety of each treatment and out of that average fruit weight was calculated of each treatment for each variety and expressed in gram wt per plant.

Fruit setting percentage

It is calculated by dividing the total number of fruits out of total number of flower multiplied with hundred for each plant.

$$\text{Fruit set percentage} = \frac{\text{Number of fruits}}{\text{Number of flowers}} \times 100$$

Average length and breadth of fruits (cm)

Average of length and breadth of fruits were recorded from each variety and treatment and expressed in centimetre.

Yield per plant (g)

Average fruit yield was recorded after harvest from each variety and expressed in grams per plant.

$$\text{Harvest Index: } \frac{\text{Economic yield}}{\text{Total biomass}} \times 100$$

Statistical analysis for Factorial completely randomized design (FCRD)

The data collected from the experiment on various aspects of yield and yield attributing characters of tomato under water logging were arranged in appropriate tables according to the treatment and were subjected to statistical analysis appropriate to the FCRD design with the help of the "Statistical procedures for agricultural research" by Gomez, K.A. and A.A. Gomez, (1984).

Results and Discussion

Days to flowering and Days to fruit maturity

Tomato plants subjected to water logging was different flowering and fruit maturity days presented in Table no-1 revealed that days to flowering and fruit maturity was delayed in 2 days water logged condition followed by 1 day water logging than control in all the treatments. About 3 to 5 days delay in flowering was recorded in 1 days water logged condition than control and additional 4-6 days delay was also observed in 2 days water logging situation than the former. However flowering to fruit maturity days vary from 16 to 20 days with in the variety. Fruit maturity in U. Pragyan was found earliest among the treatments (19days). This suggested U. Kumari could be a way out for avoiding the deleterious effects of waterlogging and could be beneficial for yielding early under waterlogging (Vincent *et al*., 2010) [15].

Number of flowers and fruits per plant

The number of fruits per plant was recorded in the Table -3, revealed that there were decrease in numbers of fruit in each variety and each treatment over control. Maximum numbers of fruits were recorded in U. Kumari (12.3) under control condition but there was a significant decrease in fruit numbers with respect to the water logging. A percent decrease of 20.4 and 44.5% in 1 day and 2 days of water logging respectively in U. Kumari and was minimum. Highest percentage in decrease in number of fruits were recorded in U. Pragyan under 2 days of water logging (52.2%) followed by U. Pallavi and U. dipti. Root hypoxia markedly reduces the anthesis, flower and fruit production due to production and accumulation of high amount of ethylene (Grichko and Glick 2001) [6]. Due to lack of oxygen and aerobic respiration at root zone under waterlogging resulted a significant loss in fruit yield because of reduction in dry matter partitioning and shoot dry weight Heeb *et al.*, (2005) [7].

Fruit setting percentage (%)

The percent fruit set were calculated by total number of fruit set out of total number of flower and presented in the Table-3. There was a significant decrease in percentage fruit setting under water logging condition over control, which is consistent with Kozlowski work (1997) [9] that stagnant water have detrimental effect on anthesis, fruit set, fruit enlargement and it also prevents flower bud initiation. However the varietal performance was not significant but its interaction with water logging was found statistically significant. The fruit setting of different cultivars in control was found 75.2%, 70.9%, 78.8% and 71.5% in U. Pallavi, U. Dipti, U. Kumari and U. Pragyan respectively found non-significant among varieties. However treated plants of the above cultivars was significantly decreased over the control in a trend of S0>S1>S2. Highest fruit setting percent was obtained in U. Kumari followed by U. Pallavi, U. Dipti and U. Pragyan. U. Kumari. The variety and stress interaction was also found statistically significant.

Average fruit weight (g)

A significant decrease in average fruit weight under water logging for both 1 and 2 days were recorded and presented in Table 2. The variety U. Kumari was maximum in average fruit weight of 39.1, 36.3, 29 g under control, 1 day and 2 days of water logging respectively with a minimum decrease

7.1 and 25.8% over the control. Whereas there was a reduction of 30.5% in U. Pallavi in 2 days of stagnant water and was found maximum.

Fruit length and breadth (cm)
Data with regards to length and width of fruits were recorded in Table-4. A significant decrease in both length and breadth of fruits in tomato under the water logged condition. 2.7 to 9.1% reduction in length and 3.03 to 16.6% reduction in breadth of fruit was observed under 1 day of water logging condition. U. Kumari was showing minimum percent decrease in length (3%) and breadth (9.0%) in length and breadth under 1 day of stagnant water over control followed by U. Pallav I, U. Dipti and U. Pragyan. The highest percentage decrease in both fruit length and width were recorded in U. Pragyan. The interaction between variety and treatment was found statistically non-significant.

Harvest Index (%)
The harvest index was calculated in percent basis in proportion to fruit yield and total biomass on dry weight basis and was presented in Table-2. The decrease in HI was in a way of S0>S1>S2 but in comparison to the variety and treatment HI was found maximum in U. Kumari followed by U. Pallavi, U. Dipti and U. Pragyan and was 80.8, 77.3, 77.2 in control, 1day and 2 days of water logging respectively. The data analyzed for HI was found statistically significant within the variety among the treatments and in relation to their interaction. Comparatively tolerant genotype U. Kumari have shown relatively less reduction in yield as compared to susceptible one due to high dry matter partitioning and the result consistent with the work of (Kumar *et al*., 2013) [10] in moong bean.

Yield per plant (g/plant)
Significant decrease in yield was recorded in treated plants than the control and was presented in Table -5 for all the treatments of the experiment. The decrease in yield was recorded among the varieties Dennis *et al.*, (2000) [3]. Maximum yield per plant was found in the cultivars U. Kumari in all the treatments with a tune of 480.9,337.5 and 223.3 g per plant followed by U. Pallavi U. Dipti and U. Pragyan respectively. Percentage decrease of yield in U. Kumari was found 29.8% in 1 day water logging and 53.6% decrease in 2 days of water logging. More over statistically significant yield per plant was recorded among the varieties in the treated plants and in between the interaction of variety and water logging. Though decrease in the yield trend was S0>S1>S2. Under partially submerged or waterlogging a decrease in yield might be due to low nutrient uptake and poor dry matter partitioning Dresboll and Kristensen (2012). which was consistent with the finding of Polthanee (2006).

Conclusion
Out of four U. Kumari showed better adaptation to waterlogging than others. It was least affected due to its efficient photosynthetic capacity and dry matter partitioning. It could be considered as a superior trait for further QTL analysis in breeding programs.

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Table 1: Effect of water logging on days to flowering and fruit maturity

Treatment		Days to flowering			Days to fruit maturity		
U. Pallavi	S0	78			98		
	S1	82			102		
	S2	87			110		
U. Dipti	S0	80			99		
	S1	84			103		
	S2	88			110		
U. Kumari	S0	75			95		
	S1	78			98		
	S2	82			103		
U. Pragyan	S0	84			100		
	S1	89			107		
	S2	93			112		
		V	S	V x S	V	S	V x S
SE(m)±		2.333	2.021	NS	1.333	1.155	NS
CD 5%		6.810	5.897	NS	3.891	3.370	NS
CV %		8.40			3.88		

- S0-Control, S1-1 day of water logging and S2-2 days of water logging
- Data presented as mean value of 3 replications

Table 2: Effect of water logging on Average fruit weight (g) and HI

Treatment		HI (%)			Average fruit weight (g)		% decrease over control
U. Pallavi	S0	80.2			35.3		-
	S1	76.0			32.5		7.9
	S2	65.3			24.5		30.5
U. Dipti	S0	77.6			38.1		-
	S1	70.2			31.2		18.1
	S2	68.4			27.4		28
U. Kumari	S0	80.8			39.1		-
	S1	77.3			36.3		7.1
	S2	74.2			29		25.8
U. Pragyan	S0	63.7			22.3		-
	S1	55.2			19.4		17.4
	S2	46.7			15.8		29.1
		V	S	V x S	V	S	V x S
SE(m)±		0.429	0.372	0.743	0.680	0.589	1.179
CD 5%		1.253	1.085	2.170	1.986	1.720	3.439
CV %		2.13			7.19		

- Data presented as mean value of 3 replications
- S0-control, S1-1day of water logging and S2-2 days of water logging
- Figure in parentheses indicates % decrease over control

Table 3: Numbers of flowers, Numbers of fruits and Percentage fruit set in response to water logging

Treatment		Flower no per plant			Fruit no per plant			Fruit setting percentage		
U. Pallavi	S0	14.3			10.7			75.2		
	S1	11.3 (21.0)			8.0 (25.2)			70.7 (5.5)		
	S2	8.7 (39.2)			5.3 (50.5)			62.0 (18.6)		
U. Dipti	S0	13.3			9.3			70.9		
	S1	9.7 (27.1)			6.0 (43.0)			62.3 (11.7)		
	S2	9.0 (32.3)			5.3 (45)			59.4 (16.4)		
U. Kumari	S0	15.7			12.3			78.8		
	S1	13.3 (15.3)			9.8 (20.4)			73.6 (6.5)		
	S2	10.7 (31.8)			7.7 (44.5)			71.9 (8.7)		
U. Pragyan	S0	9.3			6.7			71.5		
	S1	6.3 (32.3)			4.0 (40.2)			63.3 (11.1)		
	S2	5.7 (38.7)			3.2 (52.2)			56.1 (22)		
		V	S	V x S	V	S	V x S	V	S	V x S
SE(m)±		0.356	0.308	0.616	0.304	0.264	0.527	NS	2.624	5.248
CD 5%		1.038	0.899	1.798	0.888	0.769	1.538	NS	7.659	15.317
CV %		10.06			12.59			13.57		

- S0-control, S1-1day of water logging and S2-2 days of water logging
- Figure in parentheses indicates % decrease over control
- Data presented as mean value of 3 replication

Table 4: Length and breadth of fruit in cm in response to water logging

Treatment		Fruit length			Fruit width		
U. Pallavi	S0	3.9			2.8		
	S1	3.7 (5.1)			2.7 (3.5)		
	S2	3.5 (7.6)			2.6 (7.1)		
U. Dipti	S0	3.6			3.0		
	S1	3.7 (2.7)			2.5 (16.6)		
	S2	3.4 (5.5)			2.3 (23.3)		
U. Kumari	S0	3.8			3.3		
	S1	3.8 (2.7)			3.2 (3.03)		
	S2	3.5 (3.0)			3.0 (9.0)		
U. Pragyan	S0	3.3			2.5		
	S1	3.0 (9.1)			2.6 (3.8)		
	S2	2.9 (12.1)			2.5 (7.6)		
		V	**S**	**V x S**	**V**	**S**	**V x S**
SE(m)±		0.077	0.067	NS	0.084	0.072	NS
CD 5%		0.225	0.195	NS	0.244	0.211	NS
CV %		6.69			9.12		

- Data presented as mean value of 3 replications
- Figure in parentheses indicates % decrease over control
- S0-control, S1-1day of water logging and S2-2 days of water logging

Table 5: Yield per plant (g) in response to water logging

Treatment		Yield(g) per plant		% decrease over control
U. Pallavi	S0	367.0		-
	S1	260		29.2
	S2	129.8		64.6
U. Dipti	S0	354.3		-
	S1	187.2		47.2
	S2	145.2		59.0
U. Kumari	S0	480.9		-
	S1	337.5		29.8
	S2	223.3		53.6
U. Pragyan	S0	149.4		-
	S1	83.4		44.2
	S2	50.5		66.2
		V	**S**	**V x S**
SE(m)±		6.067	5.254	10.508
CD 5%		17.706	15.333	30.667
CV %		7.89		

- S0-control, S1-1day of water logging and S2-2 days of water logging
- Figure in parentheses indicates % decrease over control
- Data presented as mean value of 3 replications

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