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Research Article

Effect of the Waterlogging Period at Different Crop Growth Stages on Growth and Yield of Kharif maize

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Abstract

At present uneven and unpredictable distribution of rainfall and more precipitation in short time causes the water logging problems. To find out the effect of water logging on maize growth and yield carried out an experiment during the kharif season 2019 in student research farm at Dr. RPCAU, Pusa (Bihar). The experiment was laid in split plot design with three main plot treatments were crop growth stages and four sub-plot treatments were water logging period. The main plot treatments were 1) water logging at seedling stage, 2) water logging at knee high stage and 3) water logging at 50% Tasselling stage and sub-plot treatments were 1) 6-hour water logging, 2) 12-hour water logging, 3) 18-hour water logging and 4) 24-hour water logging with three replications of each treatment. Water logging at different growth period and water logging period significantly affected the growth parameters, yield attributes and yields. The growth parameters like plant height, dry matter production (g/plant) and crop growth stage (g/m^2/day) at 30, 60 and 90 DAS and at harvest were significantly affected by water logging at different growth stages. Water logging at seedling stage significantly decreased the all-growth parameter as compared to 50% Tasselling stage. Similarly, water logging period also significantly affected the plant height, dry matter production (g/plant) and crop growth stage (g/m^2/day) at 30, 60 and 90 DAS and at harvest. Grain yield was significantly reduced by water logging of kharif maize. Water logging at seedling stage significantly reduced the grain yieldfollowed by water logging at knee-high stage as compared to water logging at 50% Tasselling stage. Minimum grain yield (44.62 q/ha) was recorded under water logging at seedling stage as compared to water logging % Tasselling stage (54.04 q/ha). Similarly, 24-hour and 18-hour water logging duration significantly reduced the grain yield (41.32q/ha) as compared to 6-hour water logging period (56.36q/ha).

Keywords: Crop Growth Rate; Knee High Stage; Seedling Stage; Water Logging; 50% Tasselling

Introduction

Maize (*Zea mays* L.), belonging to the family Gramineae, is one of the major crops globally with high genetic yield potential. In India, maize is the third most important cereal crop after rice and wheat. It is grown in both *Kharif* and *Rabi* seasons, with the *Kharif* crop occupying 85% of the cultivation area. Despite its importance, maize is highly susceptible to waterlogging, which is a common problem in regions with heavy monsoon rains like Bihar. In maize excess moisture in the root zone diminishes the availability of oxygen by creating an aerobic condition leading to reduce growth and grain yield. The excess soil moisture which will affects various growth stages of maize that result in poor kernel development and loss in yield. Maize yield reduction due to some soil water content like both soil as well as physiological drought such as water logging and flooding is important environmental factors responsible for the occurrence of water deficit in plant tissues. In crop growth water is an important component and production system help in the achievement of the full potential of high yield. For the normal growth of the maize adequate soil moisture is required at all stages of growth. Only the more quantity of water is not essential for obtaining higher yield but provides an adequate quantity of water at different growing stages of maize. For young plants waterlogging situation during germination period was not suitable to survive. High water tables in the field will restrict the growth of roots, rendering plants more vulnerable to disease, deficiency of nutrients, and drought.

Waterlogging promotes to a reduced gas exchange between root tissues and the atmosphere because the diffusion rate of gases in flooded soil is approximately 100 times lowers than in air. Over 18% of the total maize growing areas in South and Southeast Asia are frequently affected by floods and waterlogging problems. Respiration by plant roots, soil micro-flora, and fauna leads to rapid consumption of soil oxygen, resulting in hypoxia followed by anoxia. Due to the gradual decline in oxygen, plant roots low oxygen followed by no oxygen when faced with prolonged excess soil moisture. However, maize tolerance to waterlogging stress has observed significant genetic variability. At the time of summer and *kharif* season tropic the variability can be fully utilised for developing the maize varieties to excessive waterlogging stress. There is a need for proper knowledge and understanding of inheritance practice of stress tolerance in maize cultivars. This basic for an effective breeding strategy for development and management water stress. This study aims to evaluate the effect of waterlogging at different growth stages on the growth and yield of Kharif maize and assess the water use efficiency and economic viability under these conditions.

Materials and Methods

A field experiment was conducted during the *kharif* season 2019 in student research farm at Dr. RPCAU, Pusa (Bihar). The experiment was laid in split plot design with three main plot treatments were crop growth stages and four sub-plot treatments were water logging period. The main plot treatments were 1) water logging at seedling stage, 2) water logging at knee high stage and 3) water logging at 50% Tasselling stage and sub-plot treatments were 1) 6-hour water logging, 2) 12-hour water logging, 3) 18-hour water logging and 4) 24-hour water logging with three replications of each treatment. The average rainfall of the area is 1276 mm out of which nearly 965.7 mm is received during the monsoon between june to october. The average maximum temperature during the june to october differ between 37.5°C to 29.3°C and the average minimum temperature of the same period is from 26.5°C to 22.1°C whereas during the monsoon period the average minimum temperature is about 25.34°C and the maximum temperature is about 33.14°C.The details on weather situations throughout the crop growing season of attend investigation maximum and minimum temperature, rainfall and RH % were acquire from the Agrometeorology department, RPCAU, Pusa (India). Rainfall throughout the crop growing season was lower than normal except during August and October 2019 when rainfall exceeded the normal value. The total rainfall (965.70 mm) was received during the crop period of 2019 (Figure 1). Analysis of the data has been done as per the standard procedure of statistical.

Dry matter production

For recording dry matter production five plants selected randomly were uprooted from the boundary of each plot. Obtained sample oven dried at 70°C for 72 hours and subsequent weights were measured at interval of 30 days.

CGR (g/m^2/day)

The growth rate of crop has been calculated for the periodical observation concerning dry matter production by following formula

CGR = W2 - W1 /t2 - t1

Where,

W_1- Dry weight in g/m^2 at an initial period

W_2- Dry weight in g/m^2 at the end of the period

t_2-t_1- Length of a period in days

Result and Discussion

Growth parameters

Plant Height (cm)

Waterlogging at varied growth stages significantly affected the plant height of *kharif* maize. Minimum plant heights of all stages observed were under waterlogging at seedling stage than the knee

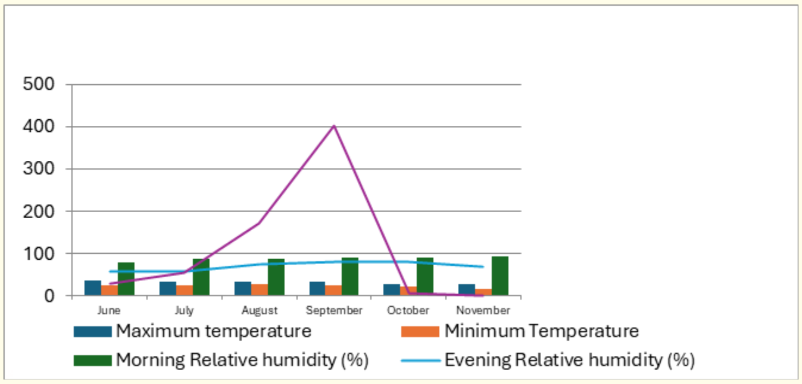

Figure 1: Maximum and minimum temperature, rainfall (mm) and RH % during crop season.

high and 50% Tasselling stage. Waterlogging during seedling stages showed that height of plants at all stages like 30, 60, 90 DAS and at harvest were 63.10, 170.81, 184.37 and 184.32 cm lowered than the waterlogging at Tasselling stage 72.98, 182.72, 200.91 and 200.84 cm (Table 1). Plant height at 30 and 60 DAS of waterlogging at knee high stage were at par with waterlogging at 50% Tasselling stage while, 90 DAS and at harvest plant height of waterlogging at knee high stage (190.30 and 190.24 cm) it were significantly lowered than the waterlogging at 50% Tasselling stage (200.91 and 200.84 cm).

Similarly, Negative impact of waterlogging period was observed on plant height that decreasing plant height with increasing waterlogging duration from 6-hour to 24-hour waterlogging. 24-hour waterlogging period observed significantly lowered plant height at all stages and which was at par with 18-hour waterlogging period related to 12 and 6-hour waterlogging duration.

Plant dry matter production (g/plant)

Minimum plant dry matter production of all stages observed under of *kharif* maize was under waterlogging at seedling stage than the knee high and 50% Tasselling stage. Waterlogging at seedling stages showed that plant dry matter accumulation at 30, 60, 90 DAS and at harvest were 7.48, 141.19, 174.92 and 191.88g/plant lowered than the waterlogging at Tasselling stage 8.11, 170.17, 236.23 and 248.52g/plant (Table 1).

Treatments	Plant height (cm)				Plant dry matter production (g plant^{-1})			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
Growth stages								
S_1-Seedling stage	63.10	170.81	184.37	184.32	7.48	141.19	174.92	191.88
S_2-Knee high stage	72.82	181.38	190.30	190.24	8.03	157.89	211.85	227.02
S_3-50% Tasselling	72.98	182.72	200.91	200.84	8.11	170.17	236.23	248.52
SEm^{+-}	1.35	1.47	1.17	1.17	0.12	2.32	3.09	3.36
LSD (p=0.05)	5.29	5.78	4.58	4.58	0.46	9.11	12.15	13.21
Duration of waterlogging								
D_1-6 hours waterlogging	73.47	181.35	200.18	200.12	8.36	171.55	228.73	242.67
D_2- 12 hours waterlogging	71.52	180.15	194.02	193.96	8.06	162.14	214.19	231.34
D_3- 18 hours waterlogging	68.27	176.51	189.40	189.34	7.72	152.17	199.57	215
D_4- 24 hours waterlogging	65.26	175.20	183.83	183.77	7.37	139.79	188.17	200
SEm^{-+}	1.72	1.50	2.19	2.19	0.12	2.41	3.21	3.49
LSD (p =0.05)	5.11	4.45	6.51	6.51	0.36	7.15	9.53	10.36
LSD (p = 0.05) Interaction	NS	NS	NS	NS	NS	NS	NS	NS

Table 1: Effect of waterlogging at varying growth and water logging period on plant height (cm) and plant dry matter production (g plant^{-1}) of *kharif* maize.

Similarly, decreasing dry matter production with increasing waterlogging duration from 6-hour to 24-hour water logging. 24-hour waterlogging period observed significantly lowered dry matter production at all stages at 30, 60, 90 DAS and at harvest of 24-hour waterlogging were 7.37, 139.79, 188.17 and 200.89g/plant *fb* 18-hour waterlogging period 7.72, 152.17, 199.57 and 215g/plant compared to 6-hour waterlogging period 8.36, 171.55, 228.73 and 242.67g/plant.

Crop growth rate (g/m^2/day)

Data table 2 showed that crop growth rate of *kharif* maize was significantly affected by different growth stages waterlogging. CGR at 30, 60, 90 DAS and at harvest were 2.08, 37.14, 9.37 and 9.42 g/m^2/day lowered recorded in waterlogging at seedling stages showed that than the waterlogging at Tasselling stage 2.25, 45.02, 18.35 and 6.83 g/m^2/day. Lower plant height at seedling stage waterlogging stress might be due to inactive of root to absorb the water and nutrient from soil because root being an important plant organ that assimilate water and nutrients from soil [1]. Previous studies showed that the well-developed roots make sure enhanced photosynthetic efficiency and plant stability but water logging reduced root number, root length and root/shoot ratio [2], thus intercept the water and nutrients absorption that reduced the plant height [3]. Waterlogging at seedling stage offered declining of stomatal conductance and chlorophyll concentration in maize seedlings that reduced the net photosynthetic rate and devastation of electron transport system [4,5].

Treatments	Crop growth rate (g/m^2/day)				Grains cob^{-1}	Grain yield (q ha^{-1})
	30 DAS	60 DAS	90 DAS	At harvest		
Growth stages						
S_1-Seedling stage	2.08	37.14	9.37	9.42	351.28	44.62
S_2-Knee high stage	2.23	41.63	14.99	8.43	393.63	49.50
S_3-50% Tasselling	2.25	45.02	18.35	6.83	419.41	54.04
SEm^{+-}	0.03	0.61	0.21	0.15	6.10	1.08
LSD (p = 0.05)	0.13	2.40	0.84	0.59	23.93	4.23
Duration of waterlogging						
D_1-6 hours waterlogging	2.32	45.33	15.88	7.74	456.45	56.36
D_2- 12 hours waterlogging	2.24	42.80	14.46	9.53	414.27	52.14
D_3- 18 hours waterlogging	2.14	40.13	13.16	8.57	363.24	47.71
D_4- 24 hours waterlogging	2.05	36.78	13.44	7.07	318.48	41.32
SEm^{-+}	0.03	0.63	0.22	0.15	12.22	0.94
LSD (p = 0.05)	0.10	1.88	0.66	0.46	36.30	2.78
LSD (p = 0.05) Interaction	NS	NS	NS	NS	NS	NS

Table 2: Effect of waterlogging at varying growth and water logging period on crop growth rate (g/m^2/day), grains cob^{-1} and grain yield (q ha^{-1}) of *kharif* maize.

Negative impact of waterlogging period was observed on crop growth rate that decreasing crop growth rate with increasing water logging duration. CGR recorded lowest at 30, 60, 90 DAS and at harvest of 24-hour waterlogging were 2.05, 36.78, 13.44 and 7.07 g/m^2/day compared to 6-hour waterlogging period 2.32, 45.33, 15.88 and 7.74 g/m^2/day. All gowth parameters growth reduced may be due to increased water logging duration reduced the total number of nodal roots, length of nodal roots, death of the root and also restricts nutrients uptake by decreasing water loss as transpiration and inhibiting function of root that declines plant height Liu *et al.,* 2013 [6] reported that reduction in plant height is directly associated with flooding duration Waterlogging stress reduced the chlorophyll photosynthetic pigment that is an abiotic stress sensitive indicator [7] And also cause leaf senescence thus influencing the photosynthetic products accumulation, resulting in biomass reduction [8,9].

Yield and Yield Attributes

Number of grains cob^{-1}

Results showed that in data table number of grains per cob significantly reduced by water logging at different growth stages. Lowest number of grains per cob was noted under water logging at seedling stage (351.28) *fb* knee-high stage water logging compared to 50% Tasselling stage water logging (419.41). 24-hour water logging period observed significantly lowered grains per cob (318.48 grains per cob) *fb* 18-hour water logging period compared to 6-hour water logging period of 456.45 grains per cob.

Yield (q ha -1)

Grain yield of *kharif* maize were significantly affected by the water logging at different growth stages and water logging period (Table 2). Water logging at different growth stages declined the grain yield, stover yield and stone yield of *kharif* maize. Minimum values of grain yield, stover yield and stone yield of *kharif* maize were observed under water logging at seedling stage *fb* knee-high stage water logging compared to water logging at 50% Tasselling stage. Minimum grain yield (44.62 q/ha) recorded under water logging at seedling stage followed by knee-high stage (49.50 q/ha) compared to water logging at 50% tasselling stage (54.04 q/ha). It may be due to the negative impacts on reproductive performance offer by waterlogging situation because of delay in silking exhibiting the lengthening of period amongst male and female flowering. A higher index for Anthesis Silking Interval (ASI) is an indication of a lower tolerance [10,11]. Rathore and his co-workers (1998) [12] described that in waterlogged conditions, yield of maize was 25 negatively correlated with ASI and decline in leaf nutrition promoted by waterlogging offered a reduction in "sink" properties and influenced the normal "source" characteristics of photosynthetic and grain filling, delivering a significant decline in grain weight and yield.

Similarly, water logging period also significantly affected the grain, stover and stone yield of *kharif* maize. Negative impact of water logging period was observed on grain, stover and stone yield. 24-hour water logging period observed significantly lowered grain, stover and stone yield. Minimum grain yield (41.32 q/ha) were obtained under 24-hour water logging period *fb* 18-hour (47.71 q/ha) and 12-hour water logging period (52.14 q/ha) compared to 6-hour water logging duration (56.36 q/ha). This might be due to increase the waterlogging duration decreased the growth parameters and yield attributes that ultimately decreased the yield of grain and stover. Palwadi and Lal, 1976 [13] reported that increases waterlogging duration affected the anthesis silking interval resulted poor pollination take place that lead to decreased the grain yields. Lizaso and Ritchie (1997) [14] also reported excess moisture in the root zone resulted in enhanced senescence of leaf and decreased photosynthesis that reduced the grain yield [15,16].

Conclusion

The growth parameters like plant height, dry matter production (g/plant) and crop growth stage (g/m^2/day) at 30, 60 and 90 DAS and at harvest and yield and yield attributes were significantly affected by water logging at different growth stages. Water logging period also significantly affected the plant height, dry matter production (g/plant) and crop growth stage (g/m^2/day) at 30, 60 and 90 DAS and at harvest and yield and yield attributes.

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