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Research Article

Effect of Foliar Application of Mannitol on Growth and Yield of Maize under Different Water Regimes

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Abstract
Maize is an important cereal crop in world. Due to the climate change the temperature has increased and water availability is reduced. Both factors limit yield potential of major cereal crops. Uniform and vigorous stand establishment is the main milestone for economically successful maize production program, but drought stress is the major cause of stand failure and yield reduction. Mannitol is considered essential for photosynthates activity which contributes 60-80% in many plants, it produces photosynthates in leaves that are translocated in phloem. Mannitol synthesis is normal in the cytosol of source leaves with a hexose phosphate pool with sucrose synthesis. Experiment was conducted to estimate the effect of various irrigation levels I0: Control, I1: Skip Irrigation at tasseling, I2: Skip Irrigation at dough stage and foliar application of mannitol with given concentration C0: 0 mM, C1: 2 mM, C2: 4 mM, C3: 6 mM on maize variety DS-555. This experiment was conducted at Agronomic Research Area, University of Agriculture, Faisalabad. The plants were uprooted from field at emergence, tasseling, silking, milking and physiological maturity stages and subject to oven dry method to understand the plant biomass partitioning. All parameters of stand establishment, growth and yield related parameters were evaluated in laboratory. The Fisher's ANOVA analysis of variance methodology was used to statistically evaluate the measured results, and the treatment means was valuated using the Least Significance Difference (LSD) test at a 5% probability level.

Keywords: Maize, Foliar application, Irrigation, Mannitol and Yield.

Introduction
Drought is a significant environmental barrier that reduces agricultural yield by altering plant development, physiology and metabolism. Drought stress is a significant limitation on agricultural output in large number of developing nations in the world's arid and semi-arid areas (Sun et al., 2015). Scarcity is the major water issue nowadays and nobody understand its impact was face in near future (Gao and Lynch, 2016). Several studies have indicated that water stress can significantly impair germination and seedling stand (Kaya et al., 2018).
When drought occurs during the grain filling stage, maize protein components are susceptible to drought stress (Chukwuma et al., 2017). Drought has an effect on the plant from germination through maturity, with a larger loss in yield during the reproductive phase than during the vegetative and grain filling phases (Queiroz et al., 2019). Drought over an

extended period decreased the grain filling period and ultimately lowered maize grain output (Liu et al., 2020). Crop performance under drought conditions is a complicated issue; when drought strikes during reproductive development stage, plants minimize their need for carbon by shrinking the size of their sink, therefore reducing crop grain output (Noor et al., 2019). Drought affects maize development and yield at several periods during its life cycle. Seedling establishment, vegetative growth, flowering, and grain filling are examples of these stages. Drought stress can result in yield losses of 15%, 40%, and 60%, respectively, during the growth, pollination, and grain filling stages (Queiroz et al., 2019).

Irrigation requirement of each crop must be met to achieve higher benefits (Saleem et al., 2022). Debruin et al. (2018) studied the production and development of maize was negatively affected by skipping watering at the tasseling stage. At early and silking grain filling stages from water stress also decreased in kernel number. Roots are crucial to a plant's survival since they are the principal indicators of drought stress. Root growth, volume, thickness and number are all structural characteristics that are affected under drought stress (Zhu et al., 2010). Under mild drought stress, maize roots become extended in order to explore additional soil foils for water absorption but under extreme drought tension root length is decreased. Skip irrigation has a detrimental influence on the maize life cycle, with the reproductive development phase being the most vulnerable to water shortage.

Therefore, the present study was designed to evaluate the effect of drought stress on maize yield. To evaluate the combined effect of foliar application of Mannitol and irrigations on growth. Assessment of economic yield against Mannitol application and drought stress.

Methodology

The proposed study was designed to evaluate the effects of skip irrigation and Mannitol application at different growth stages on maize crop.

Soil physical and chemical analysis

The soil texture was sandy clay loam and belong to Lyallpur soil series. The mechanical and chemical analysis of soil given in Table 1.

Table 1. Mechanical and chemical analysis of soil.

Soil Character	Unit	Value	
		0-15 cm	15-30 cm
A. Mechanical analysis			
Sand	%	32	25
Silt	%	45	44
Clay	%	23	30
Soil textured class	-	Sandy loam	Sandy loam
B. Chemical analysis			
EC	dsm^{-1}	1.85	1.56
pH	_	7.7	8.4
Organic matter	%	1.06	0.88
Nitrogen	%	0.052	0.054
Available phosphorus	mg/kg	12.2	11.62
Available potassium	Mg/kg	37	30

Weather data

The data regarding meteorological information during growing period 2020-21 was gathered from the Weather Station at Agricultural meteorology cell, University of Agriculture, Faisalabad.

Treatments

3This trail was performed at Agronomic Research farm, Department of Agronomy, University of Agriculture Faisalabad, Pakistan, located in Faisalabad district of province Punjab, Pakistan, which was situated at the latitude 31° north and 73° south longitudes with elevation of the land beyond the sea level about 184 m. The research was done in 2021 during the autumn growing season. The DS-555 maize hybrid was utilized for research. To prepare the ground for planting, field ploughing was carried out using a rotavator and three cultivators. The seeds were sown on ridges by dibbling using R×R 75 cm distance and recommended seed rate 25kg ha-^{1} was used. N:P:K fertilizers were applied at the rate of 202:114:90 NPK kg ha -1, utilizing Urea, DAP and MOP as fertilizer sources. Potassium and phosphorus-containing fertilizers were given all at once when seeds were planted, but nitrogen was applied in three equal portions. The first dose, which made up one-third of the total, was applied at planting time, the second dose 35 days later and the third dose during reproductive stage. Following two factors and their interaction were studied to explain the effect of spraying chemical on yield performance of crop. Factor A: various irrigation levels I0: Control, I1: Skip Irrigation at tussling, I2: Skip Irrigation at dough stage. Factor B: foliar application of mannitol with given concentration C0: 0 mM, C1: 2 mM, C2: 4 mM, C3: 6 mM. When crop reached to maturity data of yield components recorded and compared by using LSD test at 5% of probability level.

Result and Discussions

Plant height

Data showed that plant height highly significantly affected by application of different concentrations of Mannitol with different irrigation regimes. The plant height of all treatments was significantly different among irrigations levels and Mannitol application (P≤0.05) shown in the analysis of variance table 1. The maximum plant height was observed in C2 (191.37 cm) where 4Mm mannitol was applied and minimum plant height in C0 (174.23 cm) where we not apply any concentration of mannitol. Irrigation data also significantly effect on plant height the maximum plant height was recorded in I2 (202.30 cm) with skip irrigation at dough stage and minimum at I0 (169.07 cm). All doses of Mannitol showed significant variation with irrigation levels and demonstrate maximum height with skip irrigations at dough stage as shown in table 4.1. The Mannitol-0 application showed the minimum plant height with control irrigation level. In some plants, sorbitol, mannitol, and galactitol are all utilized as phloem-translocated photo assimilates which help to enhance plant height. Comas et al. (2019) evaluated a study about the lowest crop production due to water scarcity around the world.

Number of Cobs per Plant

The number of cobs plant-1 of all treatments was non-significantly different among irrigations levels and Mannitol application (P≤0.05) shown in the analysis of variance table 2. All the data regarding this parameter observed as non-significant.

Number of Grain Rows

Effect of different irrigation levels on number of grain rows per cob was observed as non-significant. Mannitol significantly effect on the number of grain rows per cob as shown in table 2 maximum number of grains row were calculated in treatment C2 (15.26) where 4Mm Mannitol was applied as foliar application Fallowed by C3 and C1 and minimum number of grain rows per cob was obtained from C0 (13.41) where we not apply mannitol. The interaction of mannitol and irrigation non-significantly effect on number of grain rows per cob as given in table 2. Mannitol, an important osmolyte, is normally synthesized in large amount in many plant species (Mitoi et al., 2009).

Cob Length (cm)

Cob length is directly related maize yield. More cob length more grain lines per cob and ultimately increase number of grains cob-1 and increase the grain yield. Effect of irrigation on cob length is significant as shown in table 2. The maximum cob length (17.27 cm) was obtained where irrigation skipped at dough stage I2 and minimum cob length was recorded from I0 (16.59 cm). Mannitol significantly effects on growth and yield of maize crop. The maximum cob length was recorded in treatment C2 (18.63 cm) where 4Mm mannitol spry was applied fallowed by C3 and minimum cob length was recorded in C0 (15.55) where we not apply mannitol spray. The interaction of irrigation and mannitol non-significantly effect on growth and yield of maize crop.

It has been reported that the performance of mannitol-accumulating transgenic plant increased because the searching of reactive oxygen, rather than osmo-regulatory effects, as the plant did not build up adequate M to maintain the osmotic potential (Abebe et al., 2003, Khare et al., 2010).

100 Grain Weight (g)

Grain weight directly related with grain yield in all cereal crops. Mannitol significantly effect on grain weight maximum grain weight was recorded from C2 (36.48 g) fallowed by C3 and minimum grain weight was recorded from C1 (25.62 g). Irrigation individually and in interaction non-significantly effect on grain yield as shown in table 2.

Grain Yield

Mannitol and irrigation individually significantly effect on grain yield. But in interaction it was non-significantly effect on grain yield as shown in Table. 3. The maximum grain yield was recorded where mannitol applied at concentration 4Mm in C2 (8.23) and minimum grain yield obtained from C0 (Control) where not apply mannitol (7.20).

Maximum grain yield recorded I2 under skip irrigation at dough stage (9.22) and minimum was recorded from I0 (6.32) as given in table 2.

The enhanced uptake of nutrient with M may compete with Cr uptake which ultimately increase grain yield.

Biological Yield

The biological yield indicates the total dry matter accumulation of a plant. Mannitol and irrigation significantly effect on biological yield of maize crop as individually but in interaction the recorded data show that it was non-significantly effect as given in table 2. The maximum biological yield under different concentrations of mannitol was recorded from C2 (19.46) fallowed by C3 and minimum biological yield recorded from C0 (17.31).

Irrigation also significantly effects on biological yield of maize crop the maximum biological yield obtained from I2 (19.43) where irrigation skipped at dough stage and minimum recorded from I1 (17.24) where irrigation skip at tasseling stage.

Harvest Index

Harvest index is ratio between grain yield and biological yield. Mannitol individually effects significantly effect on the harvest index. More harvest index obtained from C2 (41.48) and minimum from C0 (35.93) under mannitol foliar application. Recorded data show that irrigation individually and in nitration non-significantly effect on harvest index as shown in table 2.

Table 2: Effect of foliar application of Mannitol on growth and yield of maize under different water regimes.

Treatments	PH	NOC	NGR	CL	100GW	BY	HI	Y
I_0=Control	169.07C	1.00	14.33	16.59B	26.79	17.62B	37.33	6.32C
I_1=Skip Irrigation at tussling	180.79B	1.00	13.94	16.95AB	30.60	17.24B	39.38	7.88B
I_2=Skip Irrigation at dough stage	202.30A	1.00	14.47	17.27A	31.07	19.43A	39.01	9.22A
LSD value	5.9867**	NS	NS	0.4885*	NS	1.2214*	NS	0.4372**
C_0=0Mm	174.23C	1.00	13.41C	15.55C	27.42B	17.31C	35.93C	7.20B
C_1=2Mm	182.70BC	1.00	13.96BC	16.23C	25.62B	16.97BC	37.57BC	7.63B
C_2=4Mm	191.37A	1.00	15.26A	18.63A	36.48A	19.46A	41.48A	8.23A
C_3=6Mm	189.40AB	1.00	14.37B	17.33B	28.45B	18.67AB	39.33B	8.18A
LSD value	8.8085**	NS	0.9084**	0.9798**	5.7126**	1.5145**	1.9272**	0.4709**
I_0 x C_0	161.37	1.00	12.89	15.19	23.16	16.00	34.59	5.70
I_0 x C_1	166.70	1.00	13.78	16.51	21.87	16.96	36.75	6.20
I_0 x C_2	177.00	1.00	16.67	17.69	34.33	19.03	40.00	6.90
I_0 x C_3	171.20	1.00	14.00	16.97	27.82	18.50	38.00	6.50
I_1 x C_0	175.00	1.00	13.33	15.80	27.50	17.27	36.78	7.10
I_1 x C_1	176.54	1.00	14.00	16.04	28.67	16.63	38.33	7.60
I_1 x C_2	185.80	1.00	14.22	18.43	37.33	18.00	41.78	8.10
I_1 x C_3	185.80	1.00	14.22	17.52	28.93	17.09	40.67	8.73
I_2 x C_0	187.70	1.00	14.00	15.67	31.60	18.67	36.42	8.80
I_2 x C_1	198.90	1.00	14.11	16.13	26.33	17.33	37.63	9.10
I_2 x C_2	211.30	1.00	14.89	19.77	37.78	21.34	42.67	9.70
I_2 x C_3	211.30	1.00	14.89	17.52	28.60	20.40	39.33	9.30
LSD value	NS	NS	NS	NS	NS	NS	NS	NS

Source: Authors computation.

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