Middle East Journal of Agriculture Research
ISSN 2077-4605
Volume : 07 | Issue : 02 | April-June | 2018
Pages:331-338

Yield and Yield Components of Maize As Influenced by Salicylic Acid under Reduced Irrigation

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Received: 09 Jan. 2018 / Accepted: 22 Mar. 2018 / Publication date: 26 April 2018

ABSTRACT

To study the yield and yield components of maize as influenced by salicylic acid under reduced irrigation, an experiment was conducted at the Agronomy Research Farm of The University of Agriculture, Peshawar Khyber Pakhtunkhwa, during summer 2015. The experiment was laid out in a randomized complete block design (RCBD) with split plot arrangement having three replications. The experiment was consisted of six Irrigation levels (I_0 = Zero irrigation, I_1 = One irrigation, I_2 = Two irrigations, I_3 = Three irrigations, I_4 = Four irrigations, and I_5 = Five irrigations in complete life cycle) which were assigned to main plots and five salicylic acid levels (SA_0 = 0, SA_1 = 150, SA_2 = 300, SA_3 = 450, and SA_4 = 600 mg L^{-1}) assigned to sub plots. Results indicated that application of four irrigations produced higher grains ear^{-1} (387). Five irrigated plots also produced, grain yield (1911 kg ha^{-1}), biological yield (5865 kg ha^{-1}), and shelling percentage (79%). All these values were statistically equal to those recorded by four times irrigations. I_5 produced highest harvest index (31%). Application of 450 and 300 mg L^{-1} SA produced highest grain yield of (1820 kg ha^{-1}) and (1693 kg ha^{-1}), and biological yield of (5139 kg ha^{-1}) and (4690 kg ha^{-1}), respectively. It was concluded that four irrigations and SA at the rate of 300 mg L^{-1} performed well in terms of significantly higher grain yield which was statistically similar with five times irrigations and SA at the rate of 450 mg L^{-1}, respectively.

Key words: Yield and Yield components of maize, Salicylic acid and Irrigation

INTRODUCTION

Maize (*Zea mays* L.) is an important cereal crop of the world and has great economic value in livestock and poultry production (Harris *et al.,* 2007). It belongs to the family poaceae and comes under the C4 category of plants. It is cross pollinated crop of determinate nature. It is the third mostly cultivated crop after wheat and rice all over the world as reported by Food and Agriculture Organization (FAO, 2002) as well as in Pakistan and especially in Khyber Pakhtunkhwa (KP). It is extensively grown in temperate, subtropical, and tropical regions. It is grown during spring and summer seasons. It can be grown on all types of soils, ranging from sandy to clayey. However medium-textured soil with pH 6.5 to 7.5 is most suitable for maize.

During 2013-2014, it was cultivated on an area of 1168.5 thousand hectares with the total production of 4944.2 thousand tons and national average yield was 4231 kg ha^{-1},while in KP it was grown on about 470.9 thousand hectares with a total production of 914.8 thousand tones and average yield was 1943 kg ha^{-1}(MNFS&R, 2014). Although, soil and climatic conditions of Pakistan are highly favorable and high yielding varieties are also available, yet the yield recovery of maize at farmer's field is low when compared with other maize producing countries like USA, Canada, and Egypt etc. Approximately 8 to 10% of the maize crop is used for human consumption (Bakht *et al.,* 2006). It is produced extensively in Nigeria, where it is consumed roasted, baked, fried, pounded or fermented (Agbato, 2003). In advanced countries, it is an important source of many industrial products such as corn sugar, corn oil, corn flour, starch, syrup, brewer's grit and alcohol (Dutt, 2005).

Generally maize need five irrigations in the complete season in Peshawar, first irrigation is

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given five to six days after emergence, second irrigation at knee height stage, third in flowering, fourth in the ear formation and fifth in the milk stage. Due to the serious water shortages the great challenge for the coming decades is the task of increasing food production with less water, particularly in countries with limited water and land resources (FAO, 2002). Therefore, techniques are needed to increase the water use efficiency. Irrigation scheduling has conventionally aimed to achieve an optimum water supply for productivity, with soil water content being maintained close to field capacity. The increasing worldwide shortages of water and costs of irrigation are leading to an emphasis on developing methods of irrigation that minimize water use and maximize the water use efficiency (Hess, 1996).

Water deficit is a major environmental factor restricting plant growth, development and productivity, particularly in arid regions more than any other single environmental factor (Huai-Fu *et al.,* 2014). Water stress affects almost every developmental stage of the plant. However, damaging effects of this stress was more noted when it coincided with various growth stages such as germination, seedling shoot length, root length, and flowering (Khayatnezhad *et al.,* 2010). Yield of maize crop is sensitive to abiotic stresses and may cause more than 50% yield reduction (Cakmak, 2005). Drought is the major abiotic stress, which affects every aspect of plant growth and is mainly responsible for limiting crop production (Golbashy *et al.,* 2010).

Salicylic acid (SA) is known as an important signal molecule for modulating plant responses to environmental stresses (Shakirova *et al.,* 2003). It is a plant phenolic white compound odorless powder, having formula $C_7H_6O_3$, and works in plant growth regulations and maintenance of certain plant hormones and enzymes. Salicylic acid can play a significant role in plant water relations (Barkosky and Einhelling, 1993), photosynthesis, growth and stomatal regulation (Khan *et al.,* 2003; Arfan *et al.,* 2007) under abiotic stress conditions. Salicylic acid is also involved in endogenous signaling to trigger plant defense against pathogens (Khan *et al.,* 2003).

Application of salicylic acid may increase stress tolerance of plants by positively altering physiological phenomena in plants. Therefore, the present study was undertaken to investigate the protective role of salicylic acid against drought stress in maize. SA and related compounds have been reported to induce significant effects on various biological aspects in plants. Salicylic acid has also been recorded to reverse the closure of stomata caused by abscisic acid (Rai *et al.,* 1986).

SA or ortho-hydroxy benzoic acid and other salicylates are known to affect various physiological and biochemical activities of plants and may play a key role in regulating their growth and productivity (Hayat *et al.,* 2010). Seed treatment or foliar application of chemicals like glycinebetaine, kinetin, salicylic acid (Gunes *et al.,* 2007; Karlidag *et al.,* 2009) may increase yield of different crops due to reduction in stress induced inhibition of plant growth (Elwana and El-Hamahmyb, 2009), enhanced photosynthetic rates, leaf area and plant dry matter production (Khan *et al.,* 2003).Application of exogenous salicylic acid improves the plant performance under water stress, as reported by several authors. Low concentrations of exogenous SA provided tolerance against the damaging effects of drought in tomato and bean plants, whereas, higher concentrations did not show the same positive results (Senaratna *et al.,* 2000). Enhanced tolerance to drought and dry matter accumulation was also observed in plants of wheat raised from grains soaked in acetyl salicylic acid aqueous solution (Hamada 1998; Hamada and Al-Hakimi 2001).The present study was conducted with aim to sort out the optimum irrigation level with the application of salicylic acid for getting higher productivity of maize under the agro-ecological conditions of Peshawar.

Materials and Methods

Experimental site

To study the effect of salicylic acid levels on the performance of maize under reduced irrigation, an experiment was conducted at the Agronomy Research Farm of The University of Agriculture Peshawar, Khyber Pakhtunkhwa, during summer 2015. The experimental field is located in Peshawar at 34° N latitude, 71.3° E longitude and 350 m above sea level (Khan *et al.,* 2004). Peshawar is located about 1600 km north of the Indian ocean and has continental type of climate. The research farm is irrigated by Warsak canal from river Kabul.

Experimentation

The experiment was laid out in a randomized complete block design (RCBD) with split plot arrangement having three replications. Each replication was consisted of 30 treatments with a plot size of 3 m x 2 m (4 rows, 2 m long) was used. The experiment was consisted of six irrigation levels (I_0 = Zero irrigation, I_1 = One irrigation, I_2 = Two irrigations, I_3 = Three irrigations, I_4 = Four irrigations, and I_5 = Five irrigations in complete life cycle) which were assigned to main plots and five salicylic acid levels (SA_0 = 0, SA_1 = 150, SA_2 = 300, SA_3 = 450, and SA_4 = 600 mg L^{-1}) assigned to sub plots. The irrigations were scheduled on the growth stages of maize i.e. first irrigation at 50% emergence, second at knee height stage, third at flowering (silking), fourth at ear formation, and fifth at milk stage, respectively. The tested salicylic acid amount was measured by electronic balance then boiled in water for complete solvation. The boiled solution was then mixed in the sprayer with cool water for its application. The SA was sprayed at knee height stage. Recommended dose of N: P: K at the rate of 120: 90: 60 kg ha^{-1} was applied from urea, DAP and SOP. Urea was applied in two equal splits i.e. 50 % at sowing, and 50 % at second irrigation (knee height), while P and K was applied at sowing time. The crop was sown on 21st June, using a seed rate of 30 kg ha^{-1}. Row to row and plant to plant distance was kept 75 cm and 20 cm, respectively to get uniform plant population. AZAM variety of maize was used as a test crop
The details of the factors and their levels were as follows.

A. Main plot factor (Irrigation)
I_0 = zero irrigation (No irrigation at all)
I_1 = one irrigation (One irrigation given at 50% emergence)
I_2 = two irrigations (I_1 + 2nd irrigation given at knee height stage)
I_3 = three irrigations (I_1 + I_2 + 3rd irrigation given at flowering stage)
I_4 = four irrigations (I_1 + I_2 + I_3 + 4th irrigation given at ear formation stage)
I_5 = five irrigations (I_1 + I_2 + I_3 + I_4 + 5th irrigation given at milk stage)

B. Sub plot factor (Salicylic acid, SA, mg L^{-1})
SA_0= 0 mg L^{-1},SA_1= 150 mg L^{-1}, SA_2= 300 mg L^{-1}, SA_3= 450 mg L^{-1}, SA_4= 600 mg L^{-1}

Statistical analysis

Statistical analysis was conducted according to RCB design with split plot arrangement. The least significant difference (LSD) test was employed to explain variation due to irrigation numbers and salicylic acid levels on maize at 5% significance level ($P \leq 0.05$) (Jan *et al.,* 2009).

Results and discussion

Grains ear^{-1}

Data regarding grains ear^{-1} of maize as affected by irrigation and SA levels are reported in Table 1. Statistical analysis of the data showed that grains ear^{-1} was significantly affected by various irrigation numbers at 5% significance level while salicylic acid levels showed non-significant effect. The interaction of irrigation and SA was also non-significant. Mean values of the data showed that four times irrigated plots produced highest grains ear^{-1} (387) followed by (362) at five irrigations as compared with lower of (301) at zero irrigated plots. Application of desired quantity of irrigation water may increase the grains ear^{-1}. Our results are supported by Taipodia and Singh (2013); Saif *et al.,* (2003) and Wajid (1990).

1000 grains weight (g)

Data regarding thousand grains weight of maize as affected by irrigation and SA levels are reported in Table 1. Statistical analysis of the data showed that 1000 grains weight was significantly affected by various irrigation numbers at 5% significance level while salicylic acid levels showed non-significant effect. The interaction of irrigation and SA was also non-significant. Mean values of the data revealed that highest 1000 grains weight (225 g) was recorded at four times irrigated plots, which was statistically at par with (210, 217 and 218) from two, three and five times irrigations, respectively as compared with lowest of (197 g) at zero irrigated plots. Our results are quite in line with those of Taipodia and Singh (2013) and Saif *et al.,* (2003) who reported that 1000 grains weight was affected significantly by irrigation frequencies.

Biological yield (kg ha^{-1})

Data regarding biological yield (kg ha^{-1}) of maize as affected by irrigation and SA levels are given in Table 1. Statistical analysis of the data showed that biological yield was highly significant by various irrigation numbers as well as SA levels at 5% significance level. The interaction of irrigation and SA was non-significant. Mean values of the data showed that five times irrigated plots produced highest biological yield (5865 kg ha^{-1}), which was statistically at par with biological yield (5142 kg ha^{-1}) recorded at four times irrigations as compared with minimum of (3384 kg ha^{-1}) at zero irrigated plots. For SA highest biological yield of (5139 kg ha^{-1}) was recorded at the application of 450 mg L^{-1}, which was statistically at par with (4690 kg ha^{-1}) at the application of 300 mg L^{-1}. The response of maize growth to irrigation and SA application and the increase in biological yield with increasing irrigation and SA levels may be attributed to the fact that irrigation enhances growth vigor in plants and SA increases the antioxidant compounds and stimulate the synthesis of new proteins. Our results are in agreement with the findings of Babar *et al.,* (2015); Ahmad *et al.,* (2014); Taipodia and Singh (2013) and Saif *et al.,* (2003).

Table 1: Grains ear^{-1}, thousand grains weight (g), Biological yield (kg ha^{-1}), Grain Yield (kg ha^{-1}) of maize as affected by application of irrigation and salicylic acid levels.

Salicylic Acid(mg L^{-1})	Grains ear^{-1}	Thousand Grains Weight (g)	Biological yield (kg ha^{-1})	Grain yield (kg ha^{-1})
0	347	204	4062 c	1612 b
150	366	215	4161 bc	1640 b
300	314	215	4690 ab	1693 ab
450	334	213	5139 a	1820 a
600	330	215	4496 bc	1658 b
Irrigations				
I0	301c	197c	3384d	1577b
I1	314c	207bc	3936cd	1598b
I2	325bc	210abc	4290bcd	1561b
I3	339b	217ab	4441bc	1612b
I4	387a	225a	5142ab	1849a
I5	362ab	218ab	5865a	1911a
Lsd (0.05) for SA	ns	ns	560.6	140.4
Lsd (0.05) For Irrigation	47.26	16.46	990.6	162.6

I_0 = zero irrigation (No irrigation at all)
I_1 = one irrigation (One irrigation given at 50% emergence)
I_2 = two irrigations (I_1 + 2nd irrigation given at knee height stage)
I_3 = three irrigations (I_1 + I_2 + 3rd irrigation given at flowering stage)
I_4 = four irrigations (I_1 + I_2 + I_3 + 4th irrigation given at ear formation stage)
I_5 = five irrigations (I_1 + I_2 + I_3 + I_4 + 5th irrigation given at milk stage)

Grain yield (kg ha^{-1})

Data on grain yield (kg ha^{-1}) of maize as affected by irrigation and SA levels are presented in Table 1. Statistical analysis of the data revealed that grain yield was highly significant by various irrigation numbers. The application of SA levels also showed significant differences. The interaction of irrigation and SA was non-significant. Mean values of the data showed that five times irrigated plots produced higher grain yield (1911 kg ha^{-1}), which was statistically at par with grain yield (1849 kg ha^{-1}) recorded at four times irrigations as compared with minimum of (1577 kg ha^{-1}) from zero irrigated plots. For SA higher grain yield (1820 kg ha^{-1}) was recorded at the application of 450 mg L^{-1}, which was statistically at par with (1693 kg ha^{-1}) at the application of 300 mg L^{-1}. Increase in grain yield might be due to the influence of irrigation and SA application on a number of growth parameters such as grain rows ear^{-1}, grains ear^{-1}, 1000 grains weight by producing more vigorous growth and development. Anjum *et al.,* (2014); Ahmad *et al.,* (2014); Zamaninejad *et al.,* (2013); Taipodia and Singh (2013); and Saif *et al.,* (2003) reported that an increase in grain yield occur with increasing irrigation and salicylic acid application.

Shelling percentage (%)

Data on shelling percentage of maize as affected by irrigation and SA levels are given in Table 2. Statistical analysis of the data showed that shelling percentage was highly significant by various irrigation numbers. The application of SA levels showed non-significant differences. The interaction of irrigation and SA was non-significant. Mean values of the data showed that highest shelling percentage (79%) was recorded at five times irrigated plots, which was statistically at par with shelling percentage (78%) recorded at four times irrigated plots as compared with minimum of (71%) at zero irrigated plots. Increase in shelling percentage might be due to increase in grains weight cob^{-1} and 1000 grains weight. Our results are in line with Hussain *et al.,* (2015).

Table 2: Shelling Percentage (%) and Harvest Index (%) of maize as affected by application of irrigation and salicylic acid levels.

Salicylic Acid(mg L^{-1})	Shelling Percentage (%)	Harvest Index (%)
0	78	26
150	74	26
300	76	28
450	75	27
600	71	26
Irrigations		
I0	71c	25c
I1	73bc	25c
I2	73bc	25c
I3	75b	27bc
I4	78a	28b
I5	79a	31a
Lsd (0.05) for SA	ns	Ns
Lsd (0.05) For Irrigation	2.98	2.54

I_0 = zero irrigation (No irrigation at all)
I_1 = one irrigation (One irrigation given at 50% emergence)
I_2 = two irrigations (I_1 + 2nd irrigation given at knee height stage)
I_3 = three irrigations (I_1 + I_2 + 3rd irrigation given at flowering stage)
I_4 = four irrigations (I_1 + I_2 + I_3 + 4th irrigation given at ear formation stage)
I_5 = five irrigations (I_1 + I_2 + I_3 + I_4 + 5th irrigation given at milk stage)

Harvest index (%)

Data on harvest index of maize as affected by irrigation and SA levels are reported in Table 2. Statistical analysis of the data revealed that harvest index was highly significant by various irrigation numbers. The application of SA levels showed non-significant differences. The interaction of irrigation and SA was non-significant. Mean values of data showed that maximum harvest index (31%) was recorded at five times irrigated plots followed by four irrigations with harvest index of (28%) as compared with minimum value of (25%) at zero irrigated plots Increase in harvest index might be due increase in physiological growth which results in more transportation of assimilates from source to sink. These results are in line with Wajid (1990) who reported that harvest index was affected significantly by irrigation frequencies.

Conclusion and Recommendation:

It was concluded that

1. Two times irrigated plots produced highest 1000 grains weight (210 g). Four times irrigated, grains ear^{-1} (387), grain yield (1849 kg ha^{-1}), biological yield (5142 kg ha^{-1}), and shelling percentage (78%) while five times irrigated plots showed highest harvest index (31%).
2. The application of salicylic acid at the rate of 300 mg L^{-1} showed highest biological yield (4690 kg ha^{-1}) and grain yield (1693 kg ha^{-1}).

On the basis of above conclusions

Four irrigations for maize are recommended due to higher grain yield and biological yield under the agro-ecological conditions of Peshawar.

The application of salicylic acid at the rate of 300 mg L^{-1} is recommended to the growers due to high grain yield and biological yield.

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