Research Article

Effect of Foliar Applied Magnesium Sulphate and Irrigation Scheduling on Quality and Yield of Maize Hybrid

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Abstract | The application of nutrients to crops at different development stages can enhance their yield and also adjust water stress levels. The aim of this study was to evaluate the effect of different levels of foliar applied magnesium sulphate and irrigation scheduling on the quality and yield of maize (*Zea mays*). Maximum cob weight without sheath (253.38 g), number of grains per cob (472.49), 1000-grains weight (265.99 g), biological yield (13.08 t ha^{-1}), grain yield (5.05 t ha^{-1}), harvest index (38.43%), grain protein contents (8.09%) and grain oil contents (4.76%) were obtained when two foliar sprays of 0.5% $MgSO_4$ (T_2) were applied. Similarly, highest cob weight without sheath (258 g), number of grains per cob (475.1), 1000-grains weight (272.5 g), biological yield (13.4 t ha^{-1}), grain yield (5.15 t ha^{-1}), harvest index (38.20%), grain protein contents (9.01%) and grain oil contents (4.76%) were recorded where irrigation was applied at 50 mm soil moisture deficit (I_2). Two foliar sprays of 0.5% 0f $MgSO_4$ (1st after 20 days of sowing and 2nd after 30 days of sowing) and irrigation at 50 mm soil moisture deficit were recommended for the improvement of quality and yield of maize.

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Keywords | Grain protein contents, Oil contents, Soil moisture deficit, Water stress, *Zea mays*

Introduction

Maize (*Zea mays* L.) is one of most imperative cereal in Pakistan. It is serving as staple food for many countries. Maize is the third important cereal crop in the world after wheat and rice on the basis of area and production (Shevkani et al., 2014; Kaur et al., 2015). In addition to use as food and feed for livestock and poultry, maize grains are also utilized in many other commercial and industrial products. For human consumption it is processed into a lot of products such as corn flour, pop corns, gruels, porridges, bread, beverages, snacks and pastes (Ortiz-Monasterio et al., 2007; Menkir, 2008). In Pakistan, it is grown on an area of 1144 m ha^{-1} with its production of 4.920 million tons which is 0.3% less than the previous year and is also lower than other maize producing countries (Economic Survey of Pakistan, 2016). The production of maize is enhanced using hybrid seeds and favorable environmental condition.

Magnesium is a macronutrient required for chlorophyll synthesis. Magnesium forms the center of the chlorophyll molecule and thus is indispensable for photosynthesis by plants as an activator of numerous enzymes and it is also a structural component of ribosome. Magnesium is related to the synthesis of oil, along with Sulphur it brings significant increase in oil contents of several crops (Marshchner, 1986). Magnesium enhanced the drought tolerance and also played an imperative role in the plants (Thalooth et al., 1990). Magnesium plays a vital role in all the biochemical and physiological processes of plants by different pathways such as metabolism of carbohydrates, activation of enzymes, chlorophyll formation, energy transfer and synthesis of proteins (Cakmak and Yazici, 2010).

The foliar application of different nutrients on different crops improves the tolerance mechanism in crops; consequently, yield of crops is also enhanced. The application of nutrients at different stages of crop can enhance its yield and also repairs its water stress level by tolerance mechanism (Lavon et al., 1999). Nutrient supply improves the performance of many different functions in plants such as to activate the various enzymes, building of proteins, regulation of photosynthesis and ultimately the yield of crops is increased (Nguyen et al., 2002). The foliar application of potassium improves water relation parameters in broad-leave crops and in response crops show more tolerance against drought (Aown et al., 2012).

Protein contents in maize grain are ranged from 9-11% (Shewry, 2007), 8.91-11.65% (Idikut et al., 2009) and 6.59-8.16% (Ali et al., 2010). This variation in maize grain protein contents was due to effect of environment and genotype (Scott et al., 2006). Plant oil contents are essential reproducible reserve for biodiesel production and for nutrient supply to humans and animals (Zheng et al., 2008). Grain oil contents in maize ranged from 2.39-3.92%. Intensity of water stress and temperature, type of genotype and days taken to maturity are major factors affecting protein and oil contents of maize grain (Ali et al., 2010).

Maize grain yield as a result of Mg (0. 25 and 45 kg ha^{-1}) application, in the form of $MgSO_4$ ranged from 1.3 to 2.8 t ha^{-1} representing 0.6 to 16.5 % increase over control (Abunyewa and Mercer-Qurashie, 2004). Simple correlation coefficients revealed that all the quantitative yield constituents were positively and significantly correlated to maize grain yield (El-Tantawy et al., 2007). Farre and Faci (2009) estimated the response of maize (*Zea mays* L.) to insufficiency of irrigation. Results showed that water deficit resulted in reduction of biological yield, kernel yield and harvest index. Average crop yield with deficit irrigation at blooming was considerably lower than that of the fully irrigated treatments. Yield reduction was due to lower number of grains m^{-2}. Keeping in view the above facts, the present study was conducted to improve the yield and quality of maize under different irrigation schedules through foliar applied $MgSO_4$.

Materials and Methods

Experiment was performed during autumn season 2014 at the research area of Agronomy, University of Agriculture, Faisalabad (31°43′ N, 73°07′ E), Punjab, Pakistan. A triplicate complete randomized block design (RCBD) with factorial arrangement was used with 5 m × 3 m plot size.

The experiment consisted of two factors. 1) four levels of foliar sprayed $MgSO_4$, (T_0 = Control, T_1= one foliar spray of 0.5% $MgSO_4$ at 20 days after sowing), T_2 = two foliar sprays of 0.5% $MgSO_4$ (1st at 20 days after sowing, 2nd at 30 days after sowing) and T_3= three foliar sprays of 0.5% $MgSO_4$ (1st at 20 days after sowing, 2nd at 30 days after sowing and 3rd at 45 days after sowing); and 2) Three levels of irrigation scheduling such as I_1=25 mm soil moisture deficit, I_2 =50 mm soil moisture deficit and I_3=75 mm soil moisture deficit were used for this experiment.

After rauni irrigation (pre planting land soaking) field was cultivated 2-3 times with the help of a tractor. Maize hybrid (HYCORN-984) was sown in the 3rd week of July, 2014. The sowing was done with a drill, plant to plant distance was 20 cm and row to row distance was 75 cm. Seed rate was 25 kg ha^{-1}. All other agronomic practices were kept uniform.

Magnesium sulphate solution with concentration of 0.5 % $MgSO_4$ was prepared adding 5 g magnesium sulphate in one liter of water respectively. Foliar application was done thoroughly by using knapsack sprayer with hollow cone nozzle. Calibration was done before spraying. Customarily, the requirement is 400 L of water to spray on an area of one hectare.

Total water requirement of spring maize is 1569 mm ha^{-1} including rauni irrigation. CROPWAT program was used for irrigation scheduling (Smith and FAO, 1992).

In addition to foliar application of magnesium sulphate other fertilizers were applied as 300-150-125 kg ha^{-1} NPK, respectively. Half of N and whole of P and K were applied at sowing in the form of urea, di-ammonium phosphate and sulphate of potash while the remaining N was applied in splits. Furadon was applied 20 kg ha^{-1} after first irrigation to control insect especially maize borer and shoot fly. Hoeing was done manually. Two hoeing's were done for earthing up and to keep the crop free of weeds.

The yield parameters such as cob weight without sheath (g), number of grains per cob, biological yield (t ha^{-1}), 1000-grains weight (g), grain yield (t ha^{-1}) and harvest index (%) were observed during study. Ten cobs were randomly taken from each plot and their weight was measured by removing their sheath, the number of grains per cob was counted and then averaged. After harvesting the crop at maturity, all plants were tied up into small bundles and left in their respective plots for 5 days to reduce moisture level. The dried bundles were then weighed. Biological yield from each plot was taken and then converted into t ha^{-1}. Samples of 1000 grains were taken from each plot, counted with a seed counter and then weighed. Grain yield was also measured by shelling the cobs with Sheller and then weighed and later on converted into t ha^{-1}. The harvest index was calculated by the formula.

$$\text{Harvest index (\%)} = \frac{\text{Grain Yield } (t\ ha^{-1})}{\text{Biological yield } (t\ ha^{-1})} \times 100$$

The quality parameters such as grain protein and grain oil contents were measured by the following procedure. Method of Jackson (1958) was used for measurement of total N percentage. The protein percentage from grains was measured by multiplying the N% with 6.25 constant factors (Hiller et al., 1948). For oil analysis the representative samples from each plot were dried and ground. Oil contents in grains were determined by means of Soxhlet fat extraction method (Low, 1990).

Data were analyzed using analysis of variance (ANOVA) on Statistix 8.1 software following (Steel et al., 1997) and treatment means were compared using LSD at $\alpha = 0.05$.

Results and Discussion

Analysis of variance of cob weight without sheath (g), number of grains per cob, biological yield (t ha^{-1}), 1000-grains weight (g), grain yield (t ha^{-1}) and harvest index (%) revealed that the influence of different levels of irrigation was significant at $P<0.01$ and influence of foliar applied $MgSO_4$ was significant at $P<0.05$ on all treatments. However, their interaction ($MgSO_4$×Irrigation) was non-significant (Table 1).

Mean comparison of $MgSO_4$ levels revealed that maximum cob weight without sheath (253.38 g), number of grains per cob (472.49), 1000-grains weight (265.99 g), biological yield (13.08 t ha^{-1}), grain yield (5.05 t ha^{-1}) and harvest index (38.43%) were obtained when two foliar sprays of 0.5% $MgSO_4$ (T_2) were applied and minimum values of cob weight without sheath (247.10 g), number of grains per cob (467.92), 1000-grains weight (257.83 g), biological yield (12.87 t ha^{-1}), grain yield (4.86 t ha^{-1}) and harvest index (37.63 %) were observed in control (T_0) treatment where no foliar spray of MgSO4 was applied. While, comparison of treatments means for irrigation scheduling showed that cob weight without sheath (258.00 g), number of grains per cob (475.10), 1000-grains weight (272.50 g), biological yield (13.40 t ha^{-1}), grain yield (5.15 t ha^{-1}) and harvest index (38.20%) were significant where irrigation was applied at 50 mm soil moisture deficit (I_2) as compared to other levels of irrigation scheduling (I_1 and I_3) which were also at par statistically. The interactive effects of foliar applied $MgSO_4$ and irrigation scheduling on yield parameters were non- significant (Table 2).

Analysis of variance for quality parameters showed that the effect of foliar applied $MgSO_4$ was significant at $P<0.05$ while, effect of irrigation scheduling was significant at $P<0.01$ on grain protein contents and grain oil contents. However, interaction effects of foliar applied $MgSO_4$ and irrigation scheduling were non-significant for these traits. (Table 3).

Comparison of means for foliar applied MgSO4 levels showed that maximum grain protein contents (8.90%) and grain oil contents (4.76%) were obtained when two foliar sprays of 0.5% $MgSO_4$ (T_2) were applied while the minimum grain protein contents (8.76%) and grain oil contents (4.74%) were observed in (T_0) where no foliar spray of $MgSO_4$ was applied. While, comparison of means for irrigation scheduling levels indicated that significantly maximum grain protein contents (9.01 %) and grain oil contents (4.76%) were recorded when irrigation was applied

Table 1: *Analysis of variance (ANOVA) for yield parameters of maize.*

Source of variation	df	Cob weight with out sheath (g)	No. of grains per cob	1000 grains weight(g)	Biological yield (t ha^{-1})	Grain yield (t ha^{-1})	Harvest index (%)
Replication	2	7111.72	4424.70	15604.10	16.820	7.2400	74.87
$MgSO_4$*	3	64.02	32.91	111.10	0.070	0.0500	1.25
Irrigation**	2	964.48	393.94	1555.80	1.820	0.5600	3.94
$MgSO_4$ × irrigation^{NS}	6	0.67	0.24	0.30	0.001	0.0018	0.14
Error	22	11.89	1.50	3.1	0.020	0.0100	0.29

**Significant at P≤0.05, **Significant at P≤0.01, ^{NS} Non-significant.*

Table 2: *Comparison of means of yield parameters.*

Treatments	Cob weight without sheath (g)	No. of grains per cob	1000 grains weight (g)	Biological yield (t ha^{-1})	Grain yield (t ha^{-1})	Harvest index (%)
$MgSO_4$						
T_0	247.10 c	467.92 c	257.83 d	12.87 b	4.86 b	37.63 b
T_1	249.13 bc	469.34 b	260.37 c	12.98 ab	4.90 b	37.63 b
T_2	253.38 a	472.49 a	265.99 a	13.08 a	5.05 a	38.43 a
T_3	250.91 ab	470.19 b	263.09 b	13.02 a	4.95 ab	37.88 b
irrigation scheduling						
I_1	240.30 c	463.80 c	249.80 c	12.60 c	4.71 c	37.20 b
I_2	258.00 a	475.10 a	272.50 a	13.40 a	5.15 a	38.20 a
I_3	252.00 b	471.00 b	263.10 b	12.90 b	4.96 b	38.10 a
Interaction	NS	NS	NS	NS	NS	NS

T_0: *Control,* **T_1:** *0.5% $MgSO_4$ (20 days after sowing),* **T_2:** *0.5% $MgSO_4$ (20 & 30 days after sowing),* **T_3:** *0.5% $MgSO_4$ (20, 30 &45 days after sowing),* **I_1:** *25 mm soil moisture deficit,* **I_2:** *50 mm soil moisture deficit,* **I_3:** *75 mm soil moisture deficit. Means within the same column sharing the same letters do not differ significantly at the 5% level of LSD.* **NS:** *Non-significant.*

at 50 mm soil moisture deficit (I_2) as compared to other irrigation schedules (I_3 and I_1) which were also statistically different from each other. The interactive effects of foliar applied $MgSO_4$ and irrigation scheduling were non- significant (Table 4).

Table 3: *Analysis of variance (ANOVA) for quality parameters.*

Source of variation	Df	Grain protein contents (%)	Grain oil contents (%)
Replication	2	3.31000	0.04300
$MgSO_4$*	3	0.03000	0.00080
Irrigation**	2	0.39000	0.00440
$MgSO_4$ × irrigation ^{NS}	6	0.00040	0.00001
Error	22	0.00140	0.00009

**Significant at P≤0.05, **Significant at P≤0.01, ^{NS} Non-significant.*

All the yield parameters of maize such as cob weight without sheath (g), number of grains per cob, biological yield (t ha^{-1}), 1000-grains weight (g), grain yield (t ha^{-1}) and harvest index (%) significantly influenced maize yield. Cob weight without sheath and number of grain per cobs were increased when magnesium sulphate ($MgSO_4$) was applied after 20 and 30 days after sowing of maize. Under the drought condition the both cob weight and number of grain per cobs were decreased due to unavailability of water. Sepaskhah and Khajeehabdollahi (2005) also reported a decrease in cob weight, number of grains per cob and 1000-grains weight under water stress conditions. The foliar applied magnesium sulphate ($MgSO_4$) affected significantly cob weight and the number of grains per cob (Alam et al., 2003). The biological yield, grain yield and harvest index of maize were decreased at high soil moisture deficit (Menkir, 2008) and increased with the foliar applied magnesium sulphate (Abunyewa and Mercer-Quarshie, 2004). It is stated that the moisture stress was manifested in the reduction of biological yield (Eshghizadeh and Eshsanzadeh, 2009). It is documented that biological yield was significantly increased by the application of magnesium sulphate fertilization (Badr-uz-Zaman et al., 2002; Abunyewa and Mercer-Quarshie, 2004). The reason is that $MgSO_4$ attributed more photo synthet-

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ic activities, which ultimately resulted in more production of biological yield. The grain yield of maize was also decreased under drought and increased by foliar applied Magnesium sulphate ($MgSO_4$). It is also reported that the irrigation depth has a significant effect on grain yield (Oktem and Oktem, 2005; Tariq et al., 2003). According to Dwivedi et al. (2002) and Abunyewa and Mercer-Quarshie (2004) grain yield was significantly increased by the application of Mg and S fertilization. Harvest index of soybean was increased with increasing levels of S (Sarker et al., 2002). Similarly, it is found that harvest index increases through sulfur application in the form of $MgSO_4$ under drought stress (Togay et al., 2008).

Table 4: *Comparison of means of quality parameters.*

Treatments	Grain protein content(%)	Grain oil content(%)
$MgSO_4$		
T_0	8.76 c	4.74 b
T_1	8.81 b	4.74 b
T_2	8.90 a	4.76 a
T_3	8.84 b	4.74 b
Irrigation scheduling		
I_1	8.65 c	4.73 c
I_2	9.01 a	4.76 a
I_3	8.82 b	4.75 b
Interaction	NS	NS

T_0: *Control,* **T_1:** *0.5% $MgSO_4$ (20 days after sowing),* **T_2:** *0.5% $MgSO_4$ (20 and 30 days after sowing),* **T_3:** *0.5% $MgSO_4$ (20, 30 and 45 days after sowing),* **I_1:** *25 mm soil moisture deficit,* **I_2:** *50 mm soil moisture deficit,* **I_3:** *75 mm soil moisture deficit. Means within the same column sharing the same letters do not differ significantly at the 5% level of LSD.* **NS:** *Non-significant.*

Protein and oil contents are the major parameter affecting the palatability and nutritional value of forage crops. Our results of protein contents (8.65-9.01%) in maize grain are little bit different from Shewry (2007) and Idikut et al. (2009) who reported 9-11% and 8.91-11.65% protein content, respectively and higher than Ali et al. (2010) who recorded 6.59-8.16% protein contents in maize grain. Similarly, the results of maize grain oil contents (4.73-4.76%) are higher than Ali et al. (2010) who noted 2.39-3.92% oil contents in maize grain. This difference in protein and oil contents was due to effect of environment as well as genotype (Carvalho et al., 2005; Champolivier and Merrien, 1996; Scott et al., 2006; Specht et al., 2001; Triboi and Triboi-Blondel, 2002). Both the grain protein and grain oil contents were decreased under water stress condition. These results are in accordance with findings of Ali et al. (2010). However other studies reported that protein and oil contents of maize grain are increased by the use of S. Grain crude protein and oil contents were increased by the application of Mg and N fertilization (Rasheed et al., 2004; Malhi et al., 2007).

Conclusion

This study concluded that two foliar sprays (first at 20 days after sowing and second at 30 days after sowing) of 0.5% magnesium sulphate and irrigation level i.e. 50 mm soil moisture deficit significantly improved quality and yield of maize. This technology may help maize growers to increase the quality and per acre yield of their crop.

Author's Contributions

Muhammad Rehan Aslam: Planned and executed the research experiment.
Muhammad Maqsood: Helped in data collection.
Zahoor Ahmad: Supervised the work and provided technical input.
Sajjad Akhtar and Muhammad Rizwan: Contributed in data analysis, results explanation and manuscript preparation.
Muhammad Usama Hameed: Contributed in editing and proofreading of the manuscript.

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